Vernier

the CALIPER

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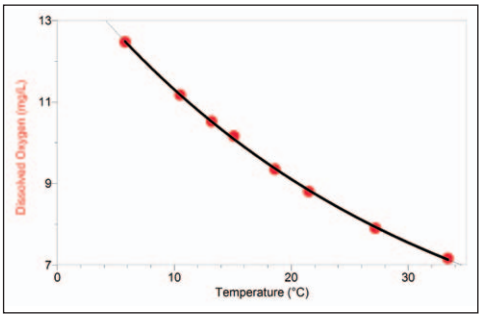
A PUBLICATION FOR USERS OF VERNIER PRODUCTS

in this issue

NEW Vernier Optical DO Probe

Measuring dissolved oxygen, DO, concentration in aqueous solutions is now easier using our new Vernier Optical DO Probe. The Optical DO Probe connects to a Vernier interface, allowing students to collect data with Logger *Pro* 3 software or LabQuest. The Optical DO Probe uses luminescent technology to provide fast, easy, and accurate measurements of dissolved oxygen concentrations, making it an excellent choice for biology, ecology, or environmental science courses.

ODO-BTA, $379



Saturated dissolved oxygen at various temperatures

This plug-and-play probe offers a switch setting to measure in units of mg/L or percent saturation and contains the following key features:

- No calibration required
- No stirring required
- No warm-up time
- No filling solution
- Built-in pressure and temperature compensation

(continued on page 12)

NEW Using Logger *Pro* 3 with iPad® and Mobile Devices

Logger *Pro* 3 is now part of the Connected Science System®! That means that you can wirelessly share data from Logger *Pro* to iPad, Android tablets, most smartphones, and even other computers.

What's the best part? Most schools won't need to spend a dime to implement this feature. For schools using older Vernier technology with Wi-Fi enabled computers, you can now stream data from Logger *Pro* 3.8.6 to iPad and other mobile devices by enabling Data Sharing during

(continued on page 11)

Logger *Pro*® 3

LP, $229

PHYSICS

NEW Vernier Radiation Monitor

Do you teach radiation in your physics, chemistry, or environmental science course? The cost of entry is now a lot lower. The new Vernier Radiation Monitor is the least expensive monitor we've ever made, yet it is just as sensitive to alpha, beta, and gamma radiation as our more expensive units.

VRM-BTD, $169

The new monitor consists of a Geiger-Müller tube mounted in a small, rugged, plastic case. A thin window protected by a metal screen allows alpha radiation to be detected, along with beta and gamma. It requires no battery, as it gets power from the data-collection interface.

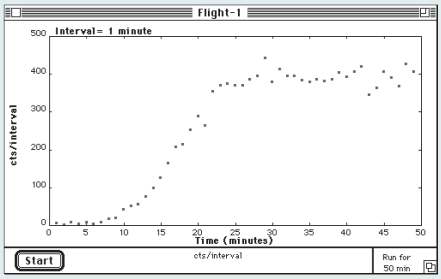
Since all the data-collection details are taken care of by LabQuest or another interface, the Vernier Radiation Monitor requires no controls or display. Using the power of Logger *Pro* or LabQuest, your students can collect counting statistics over long periods of time in order to detect small differences, such as the small additional radiation from a granite countertop. See the Innovative Use on page 3 for more details on this and other interesting experiments.

All of the experiments in the *Nuclear Radiation with Vernier* lab book can be performed with this new monitor, including "Distance and Radiation" (the inverse square law), "Lifetime Measurement," "Counting Statistics," and "Shielding." Using various shields, students can use the monitor to distinguish between alpha, beta, and gamma radiation.

Students invariably find these experiments fascinating, and this new monitor makes it easy to add them to your curriculum. For more information, visit www.vernier.com/vrm-btd

20 *years ago in the* CALIPER

In the Spring 1993 edition of *The Caliper*, we published a graph (right), showing the readings from our Radiation Monitor as we flew on a commercial airliner. This was long before we were required to turn off electronics upon takeoff. The data were taken from taxiing to 39,000 ft. We used the original ULI (with the clear plastic top), powered by 8 C batteries. A Macintosh portable computer weighing 16 pounds ran our Event Counter program. Note the count rate went from a small number to about 400 counts/min at cruising altitude.



Watts Up?

Investigating the Energy Consumed During a Charge Cycle

Which USB power adapter charges a completely dead iPad more efficiently—the large 12-watt power supply that came with the iPad or the smaller 5-watt power supply that came with the iPhone®? We decided to measure the energy consumed during the charge cycle with a Watts Up Pro.

As you can see from the graph, the larger unit uses more energy per unit of time and completes the charge cycle more quickly. But is it the same total amount of energy? To find out, we integrated under each curve.

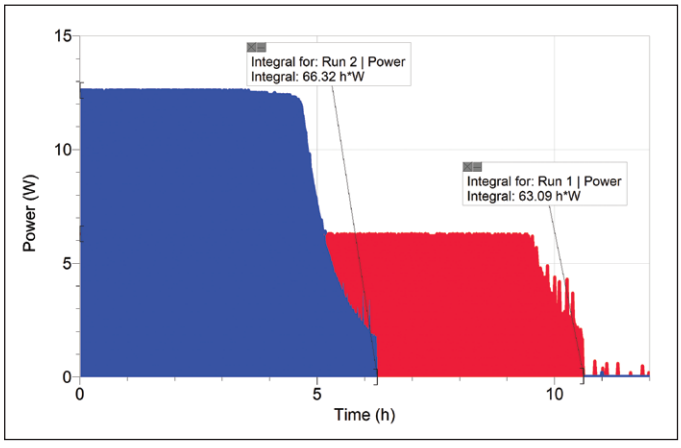
	5-watt Power Supply	12-watt Power Supply
Charge Time	10.6 hours	6.2 hours
Total Energy	63.1 watt hours	66.3 watt hours

The energy required to fully charge the battery is about the same, but there is a small difference. We did not measure temperature in this experiment. From what we have learned about rechargeable batteries in the last few years, we know that charging at a higher current generates more heat, which makes the charging process less efficient. Some people believe that consistently charging the battery at higher current can shorten its overall life. Other aspects to investigate:

- Temperature
- Off-brand chargers
- Charging while the device is on or off
- Comparing the charge cycle of different phones and tablets
- Estimating the cost of the energy to charge electronics such as laptops and tablets

WU-PRO, $145

Note that for loads lower than about 5 watts, the Watts Up Pro is not nearly as accurate as it is for household appliances such as refrigerators, freezers, and air conditioners.



Testing iPad power adapters

PHYSICS

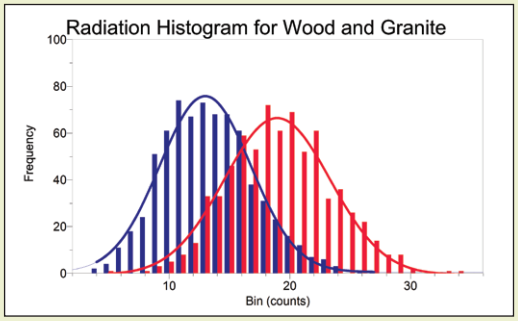
Vernier Radiation Monitor INNOVATIVE USES

What's Lurking in Your Countertops?

Don't Take Your Countertops for Granite!

A few years ago, there was a flurry of news stories warning of the dangers of radioactive granite countertops. Often caused by misinterpreted data, these claims led to public outcry and prompted the EPA to put together an FAQ regarding radioactivity in granite countertops.

Richard Born of Northern Illinois University used the new Vernier Radiation Monitor to test the radiation counts above a wooden table and a granite countertop. The counts for the granite countertop were higher, but does that make them unsafe? There are currently no regulations concerning radiation emissions from granite countertops. How do your countertops compare to the ones tested by Dr. Born?



A comparative radiation histogram showing an average count of 13 counts/min for the wood tabletop (blue) and 19 counts/min for the granite countertop (red)

Experiments to Determine the Efficiency and the Resolving Time of a Geiger-Müller Tube

Richard Born at Northern Illinois University developed an experiment for determining the efficiency of a Geiger-Müller (G-M) tube using the new Vernier Radiation Monitor. The Radiation Monitor is mounted on a wooden stand, and the radioactive source is mounted a set distance from the G-M tube end window. Radiation counts are collected for ten one-minute intervals each for background, Sr-90, and Co-60. By using the number of detected counts for the radiation source and the known number of radiation disintegrations from the source, students can calculate the efficiency of the G-M tube. His lab instructions can be downloaded at www.vernier.com/r131

Born also developed an experiment for determining the resolving time of a G-M tube using the new Vernier Radiation Monitor. By using split sources of radiation, students can determine the resolving time, *T*, by measuring the observed count rates of each source individually and then as a combined source. Full lab instructions and experimental results can be downloaded at www.vernier.com/r132

Vernier in the Science Journals

Our products are often used in innovative experiments and demonstrations described in journals. Here are some recent ones:

A Fresh Look at Longitudinal Standing Waves on a Spring

***The Physics Teacher*, January 2013, by Casey Rutherford, Shakopee High School, Shakopee, MN.** In this article, Casey explains how to use our Power Amplifier and Accessory Speaker to investigate harmonics with standing waves. He has the students explore standing waves with nodes at both ends, as well as standing waves with antinodes at one end of the spring.

Modeling the Dynamics of Gel Electrophoresis in the High School Classroom

***The Physics Teacher*, January 2013, by Skyler R. Saucedo, Palmer Trinity School, Miami, FL.** You may be wondering why Gel Electrophoresis is the topic for a physics article. It discusses the physics of how the proteins move, student misconceptions about the process, and even uses Logger *Pro* video analysis to measure the (terminal) velocity of the moving proteins.

Watching and Listening to the Coefficient of Restitution

***The Physics Teacher*, November 2012, by Jing Wang and Macro Ciocca, Eastern Kentucky University, Richmond, KY.** This article uses Logger *Pro* to study the coefficient of restitution (COR) of a bouncing ball in two very different ways. They use video analysis, deriving the COR from the heights of the bounces, but they also use a microphone and the measured time between bounces to calculate the COR and compare the results.

Lenz's Law Demonstration Using an Ultrasound Position Sensor

***The Physics Teacher*, September 2012, by Petru S. Fodor and Tara Peppard, Cleveland State University.** One of the popular demonstrations used in introductory physics courses to illustrate Lenz's law is the "slowly falling magnet." This article shows how to use our Motion Detector and Dual-Range Force Sensor to study this motion. The authors show how to plot the motion of the falling magnet and the Lenz's law force as it falls. This leads to some interesting graphs.

Chronicling a Successful Secondary Implementation of Studio Physics

***American Journal of Physics*, September 2012, by Patrick B. Kohl and H. Vincent Kuo, Colorado School of Mines.** This eight-page article describes one physics department's change from lecture/recitation/lab style courses to a lecture/Studio Physics style. They discuss the stages of their transition, benefits, challenges, and lessons learned.

Experiencing Friction in the First Grade

***Science and Children*, October 2012, by Bill Burton, The Lamplighter School, Dallas, TX.** Bill had his young students use our Force Plate to record the force it takes to drag themselves across the floor. They look at a Logger Lite graph of the force *vs.* time as they pull. The students then try pulling themselves along with the board riding on a layer of tennis balls acting as "ball bearings." It is a great, kinetic introduction to both the topic of friction and the use of graphs.

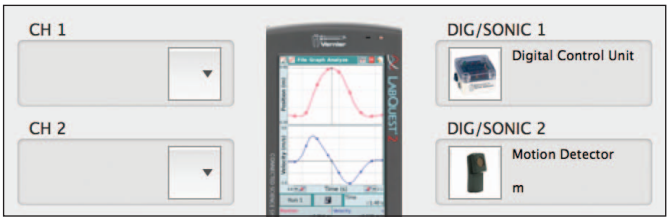
ENGINEERING

Build a Proximity Alarm in Logger *Pro*

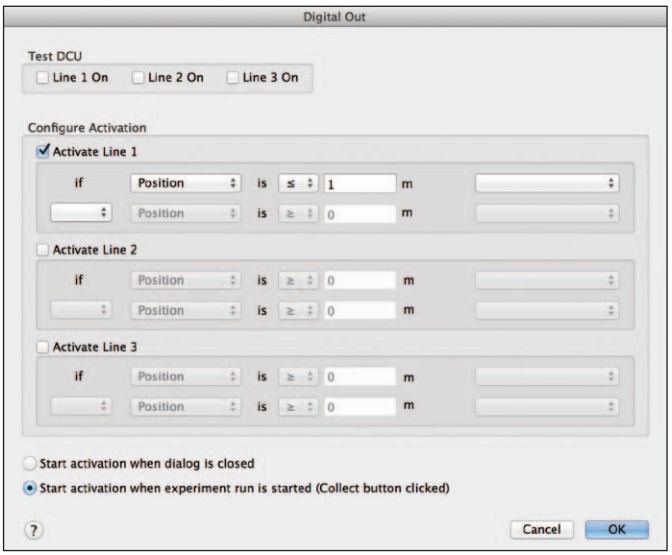
Use Logger *Pro*'s newly enhanced ability to control a Vernier Digital Control Unit (DCU) to challenge your students to create an alarm system that gives a warning when someone enters an area. The ability to turn on or off an electrical device in response to inputs from a digital sensor, an analog sensor, or time, opens up a new world of STEM challenges for your students.

The following procedure describes how to configure Logger *Pro* so that a Vernier Motion Detector monitors an area and turns on a buzzer when a person enters.

1. Connect the buzzer to line 1 of the DCU.
2. Connect the DCU (with power supply) to the digital (DIG 1) port of the interface and the Motion Detector to the digital (DIG 2) port.



3. Configure Logger *Pro*.
   a. Choose Set Up Sensors from the Experiment menu, and then select your interface.
   b. Click DIG/SONIC 1 and select Choose Sensor ▶ Digital Control Unit.



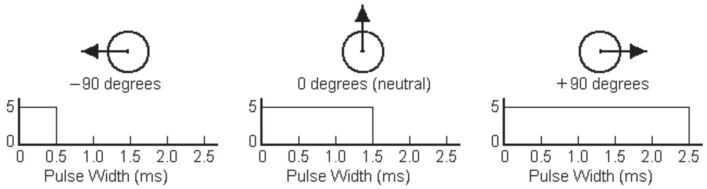
4. Configure the DCU.
   a. Click DIG/SONIC 1 a second time and select Digital Out.
   b. Select the Activate Line 1 check box.
   c. Select Less Than or Equal To (≤) and enter a threshold value, such as 1 meter.
   d. Select the check box next to Start activation when experiment run is started. Data collection begins when you click ▶ Collect.
   e. Click OK and close the Set Up Sensors configuration window.
5. Click ▶ Collect to start data collection. When someone passes within 1 meter of the Motion Detector, the buzzer should turn on.

To see the proximity alarm in action, as well as seeing Dave Vernier take on the challenge of creating an automated tea maker, check out the video at www.vernier.com/v136

Control a Servo Motor with a LabQuest

Using our latest National Instruments LabVIEW software drivers, LabQuest now has the ability to perform pulse-width modulation (PWM). PWM makes it possible to output and control square-wave pulses, which can be used to drive servo motors and control power to electrical devices. Servo motors are small, relatively inexpensive motors known for their ability to provide a large torque, or turning force. They are used in small-scale robotics applications, rack-and-pinion steering, and radio-controlled models to adjust the flaps on a plane or the rudder of a boat.

The output shaft of a standard servo motor is limited to turns within a ±90° range, with the exact location determined by the duration, or width, of a square-wave pulse sent to the input signal line. Servo motor square-wave pulses usually have widths between 0.5 and 2.5 milliseconds, as shown in the figure below. If the high voltage lasts 1.5 milliseconds, for example, it causes the servo to move to the 0° position.



PWM allows you to adjust the pulse width, controlling the position of the motor. To provide a programming challenge to your students, use a servo motor, LabQuest, and a Vernier Digital Control Unit (DCU) to vary the position of a servo motor over the full range of its motion. For more information about this project, go to www.vernier.com/r1310

In addition to controlling servo motors, PWM can be used to control power to electrical devices. Modify the length of the pulse, or the "on" time, of the PWM waveform to control the speed of a small DC motor or vary the brightness of a light.

Project ideas using PWM to control power to devices, as well as other programmable features of the LabQuest, are found in our book, *Engineering Projects with NI LabVIEW™ and Vernier*.

To perform PWM projects with your LabQuest, download the necessary NI LabVIEW software drivers from our web site, www.vernier.com/r1311

ENGINEERING

Encouraging Young Engineers

Vernier recently teamed up with a local organization, the Business Education Compact (BEC), to bring the joy of engineering to local students at Vose Elementary in Beaverton, OR. Volunteers from Vernier spent time in the fifth-grade classroom answering the questions, "What is engineering?" and "What do engineers design?"

Students at this neighborhood, Title I school then had the opportunity to build a Tower of Power, test how much load their structure could hold, redesign their tower, and then rebuild.

Volunteers from Vernier included Dr. Elaine Nam, Kristen Nelson, John Tate, Felix Rodriguez, Joe Sauer, Pam Lam, and Daylene Long.

Dear Vernier Engineers,

I had a very fun time building the towers. You guys coming into my class was something I'd been waiting for. It was really fun getting to construct shapes and build a tower. My group really messed up but we learned a lot. I really appreciate you guys coming.

After you guys came I'm now considering being an engineer in the future. I love constructing things. Since I had so much fun the day you guys came to my classroom, I think one day I would really enjoy being an engineer.

Sincerely,
Anna R.

Calibrate an Analog Sensor

Calibrating an electronic sensor is a basic STEM skill that scientists and engineers use when making precise measurements with data-collection tools. Essentially it means making hardware or software adjustments so that a sensor reads correctly. It is an important concept for students to understand so they can use sensors correctly and understand the limitations of their data. Sensor calibration can also serve as a good path into the related, but distinct, concepts of accuracy, precision, and the valid range for a calibration model.

Analog sensors measure continuous signals. Theoretically, they can produce an unlimited number of values within a given range. In the real world, the precision of an analog sensor is limited by noise in the system under measure and by the number of levels employed by the A-D converter used to import the data into a computer. Many analog sensors use a simple linear calibration, meaning the sensor reading varies in direct proportion to the sensor's voltage signal. This makes calibration relatively easy. Examples of sensors that use this type of calibration are the Vernier Dual-Range Force Sensor, pH Sensor, and Low-g Accelerometer. Other sensors use complex calibration equations, making calibration somewhat harder. Examples of such sensors are the Vernier Stainless Steel Temperature Probe, Surface Temperature Sensor, and Ion-Selective Electrodes.

Many sensors, such as the Vernier Dual-Range Force Sensor, pH Sensor, and Low-g Accelerometer, use a simple linear calibration.

We recently posted an engineering activity about linear sensor calibration on our web site. This activity challenges your students to perform a calibration using a Vernier sensor and then verify the accuracy of their model afterward. www.vernier.com/r133

Use the activity in conjunction with the sensor activities from our web site to calibrate the sensors that your students create. www.vernier.com/r134

Should you want your students to try their hands at calibrating a non-linear sensor, like a thermistor, there is an excellent discussion and procedure in the project "Build a Temperature Sensor" in our book, *Engineering Projects with NI LabVIEW™ and Vernier*. A similar activity may be found on our web site at www.vernier.com/r135

ENGINEERING & CHEMISTRY

Vernier Engineering Contest Winners

Vernier Software & Technology sponsored a contest for educators to show how they are using Vernier sensors with National Instruments LabVIEW software to introduce STEM concepts, teach LabVIEW programming, or perform engineering labs in the classroom.

The prizes for the winners included $1,000 in cash, $3,000 in Vernier technology, and $1,500 toward expenses to attend the 2013 American Society for Engineering Education (ASEE) conference in Atlanta, Georgia.

The Engineering Contest college-level award winner was Jonathan Aurnou, an associate professor from UCLA. Aurnou had students apply programming and data analysis concepts to collect data using a Vernier Light Sensor, SensorDAQ, and a rotating model of a transiting exoplanet to estimate the radius of the exoplanet.

The high-school winner was Nelson Nunalee, an engineering teacher from Ravenscroft School. Nunalee combined the study of digital music and engineering to create an opportunity for students to develop programming skills and learn STEM concepts, including fundamentals of sound and sinusoidal signals using Vernier sensors and LabVIEW software. To see the great videos submitted by the winners, visit www.vernier.com/r136

Students high five in Nelson Nunalee's winning high-school submission.

Improved Design: Vernier Mini GC Plus

The Vernier Mini GC Plus offers several additional features while maintaining easy set up. Increasing the maximum operating temperature of the column to 160°C, along with improving the MEMS chip sensor, allows for an expanded library of organic compounds that can be injected. This includes small heterocycles, halogenated alkanes, and many more.

GC2-MINI, $1,799

The improvements also offer the option to set the MEMS chip sensor at two levels of sensitivity. Standard sensitivity mode works well for polar compounds such as ketones, alcohols, and esters. High sensitivity mode works well for compounds such as halogenated alkanes and substituted aromatics, as well as mixtures with one or more compound of low concentration.

The Mini GC Plus continues to be compact, portable, and uses room air as the carrier gas. The same fundamental components of a traditional gas chromatograph remain, including an injection port, temperature and pressure controls, a thin capillary column (Restek MXT®-1 stainless-steel capillary), and a sensor for detecting the arrival of compounds.

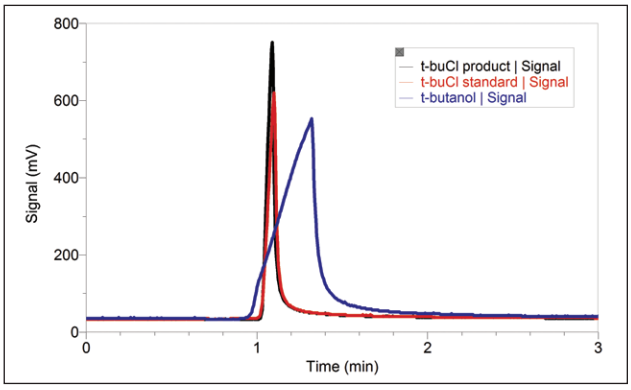
A tutorial on using the Mini GC Plus can be found in our video training library at www.vernier.com/v83

Additional information with a complete table listing the classes of compounds compatible with the Mini GC Plus can be found at www.vernier.com/gc2-mini

Investigate Halogenated Alkanes with Mini GC Plus

One of the many improvements available with the Mini GC Plus is the expanded library of organic compounds that can be injected, including halogenated alkanes. The new features for the Mini GC Plus are useful when conducting Experiment 13, S_N1: Synthesis of *tert*-Butyl Chloride from *Organic Chemistry with Vernier*.

Alkyl halides can be prepared from their corresponding alcohols via an acid catalyzed substitution reaction. The mechanism of these acid catalyzed substitution reactions are labeled as S_N1 (substitution, nucleophilic, unimolecular) and S_N2 (substitution, nucleophilic, bimolecular). Tertiary alcohols follow the S_N1 route, primary alcohols follow the S_N2 route, and secondary alcohols can follow either path.



Overlaid gas chromatograms of the synthesized product, tert-butyl chloride standard, and tert-butanol starting material

In this experiment, students prepare *tert*-butyl chloride from *tert*-butanol. Product verification is accomplished by comparing the chromatograms of the starting material, the *tert*-butyl chloride standard, and the synthesized product. To preview this experiment and additional experiments from *Organic Chemistry with Vernier*, visit www.vernier.com/chem-o

CHEMISTRY & BIOLOGY

Best Practice Techniques for the Mini GC and the Mini GC Plus

In order to prolong the life of your Mini GC (original or Plus), or to prevent having to send it in for repair, make sure you note the following best practices.

1. After receiving your Mini GC, it is best to begin with at least one experiment from the experiment book that accompanies the instrument. This will give you the best idea of compounds that come out cleanest, along with their temperature/pressure profiles.
2. The Hamilton syringe that is shipped with the device has a brown plastic bumper guard on the needle, also known as a needle stop. Do NOT remove this guard. Injections go straight into the column, and you can damage the instrument by forcing the syringe too far into the device.
3. Make sure you have referred to the list of acceptable compounds in the user guide before attempting to inject new compounds. The latest information for the Mini GC can be found at www.vernier.com/gc-mini, and the latest information for the Mini GC Plus can be found at www.vernier.com/gc2-mini
4. If you inject samples that contain more than 5% water, you will shorten the life of the detector, or you may ruin it altogether. To get the longest life out of your Mini GC, only inject between 0.2 and 0.3 µL of a pure organic sample, or 0.4–0.6 µL of a mixture of organic compounds.

If you have a particular gas chromatography application in mind, but you are not quite sure if it is appropriate for the Mini GC or Mini GC Plus, please call Vernier Technical Support at 888-837-6437 and ask to speak with a chemist. You can also email us at support@vernier.com

AP Chemistry: Changes They Are a-Comin'

If you teach AP Chemistry, you know what's coming. The College Board has made some significant changes to the AP Chemistry curriculum, and these changes go into effect with the 2013-2014 school year. We, at Vernier, have studied the new AP Chemistry Curriculum Framework and the new laboratory manual very carefully, and we have some resources to offer. Visit our web site to review the lab experiment correlations between our lab books and the AP Chemistry Framework. To view the correlations for our lab book, *Advanced Chemistry with Vernier*, visit www.vernier.com/ap-chem-a

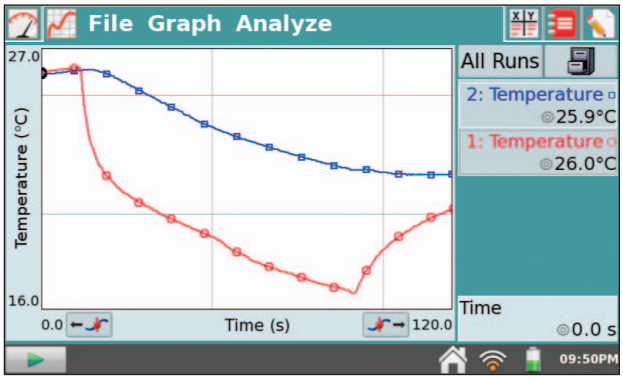
For correlations for our inquiry lab book, *Investigating Chemistry through Inquiry,* visit www.vernier.com/ap-chem-i

In addition to the curriculum changes, the College Board has published its own lab manual for AP Chemistry. The new lab manual contains sixteen experiments, written in inquiry format. For assistance in designing your lab program to the new lab guidelines set forth by the College Board, email chemistry@vernier.com

Exploring the Evolution of Temperature Regulation in Marine Mammals

Evolution is one of the "big ideas" in the new AP Biology curriculum and one of the "core ideas" in the *Framework for K–12 Science Education*, the foundation for the Next Generation Science Standards. Many teachers have been asking how our sensors can be used to teach concepts in evolution. Recently, we took a standard insulator experiment and gave it an evolutionary twist that uses the Surface Temperature Sensor (STS-BTA, $23).

Studying vertebrate ecology is an excellent way to explore adaptation and evolution. Mammals and birds are endotherms, meaning they regulate their internal body temperature using metabolic processes. Most other vertebrates are ectotherms, maintaining their body temperature through external sources. Most species of ectotherms are limited to a narrow temperature profile. In contrast, marine mammals have derived characteristics that make it possible for them to maintain their body temperature in different water temperatures. Blubber and fur are two adaptations that provide insulation to marine mammals.



The temperature of a gloved hand, covered by vegetable shortening and a bag (blue) was compared to a gloved hand with only a bag (red).

In this experiment using the Surface Temperature Sensor, students explore the properties of blubber and fur. Students attach a Surface Temperature Sensor to a gloved hand, then apply different insulating materials, such as bubble wrap and shortening. They submerge their hand in ice water and collect data to determine temperature change over time.

Vegetable shortening and bubble wrap mimic blubber and fur. Vegetable shortening has a much lower thermal conductivity than water, so its thermal properties make it analogous to blubber. Bubble wrap is composed of numerous pockets of trapped air, so its thermal properties should resemble the fur of a polar bear or sea otter. Bubble wrap is a cheap and accessible material to use as a stand in for fur or hair.

Have your students design their own insulating gloves to turn this lab into an engineering opportunity. Consider using natural limits and constraints in nature to shape the constraints of their design. Download the experiment at www.vernier.com/r137

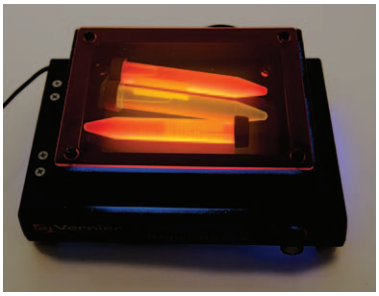
BIOLOGY

Chlorophyll Fluorescence Using the BlueView Transilluminator

The BlueView Transilluminator has a set of super bright blue LEDs that are used to illuminate fluorescent stains. It is often used to look at GFP-transformed bacterial colonies or agarose gels stained with SYBR® Safe DNA Gel Stain. But did you know that you can also use it to show that chlorophyll is fluorescent?

Demonstrating fluorescence is a relatively easy method of bringing molecular biology to life. Some molecules, when excited by specific wavelengths of light, will fluoresce by emitting a lower energy photon, as well as heat, as they return to their ground level energy state. This photon has a slightly longer wavelength than the one that excited it. In this case, chlorophyll is excited by blue light and fluoresces red light. In a functioning cell, some of this energy is converted into chemical energy rather than fluorescing. This ability to "harvest" light energy allows them to produce carbohydrates from water and carbon dioxide during photosynthesis.

To prepare a chlorophyll solution, macerate several spinach leaves in a plastic sandwich bag containing 10 to 15 mL of isopropanol. Then pour the contents of the bag through a coffee filter and collect the filtrate. Transfer the filtrate to a 20 mL test tube and stopper it securely. Place it in the BlueView Transilluminator for viewing. The orange plastic lid will filter out the blue light while allowing the red fluorescence to pass through.

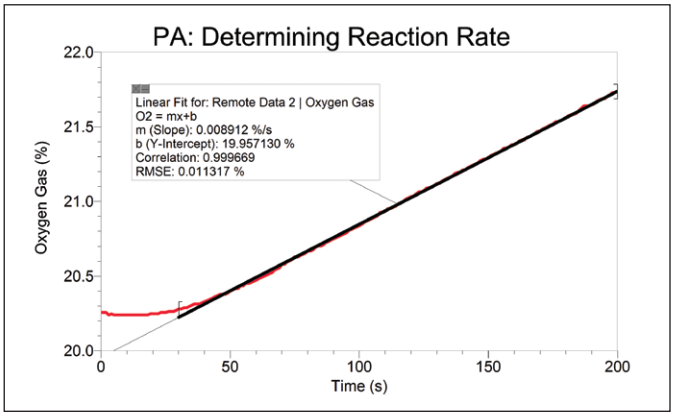


The photo (left) shows a BlueView Transilluminator containing three tubes filled with the chlorophyll filtrate. Notice the red glow as the chlorophyll fluoresces from the excitation of the blue light.

This is a great demonstration to perform when your students are conducting the "Plant Pigments" investigation in our *Investigating Biology through Inquiry* lab book (BIO-I, $48).

Tips and Tricks for Success with Inquiry-Based Enzyme Activities

Understanding enzyme action is a fundamental concept in biology. The "Testing Catalase Activity" investigation in our *Investigating Biology through Inquiry* book (BIO-I, $48) is a very popular activity for investigating enzyme action. Our O_2 Gas Sensor and Gas Pressure Sensor can be used in this activity along with some very simple materials, such as yeast and hydrogen peroxide. However, you can't just mix hydrogen peroxide with a few drops of baker's yeast and expect to get repeatable results every time. The amount of enzyme in a drop of yeast suspension depends on the number of yeast cells in each drop. This will depend on how long the yeast have grown and where the students pull each drop from the suspension. To get consistent results each time, the instructor must proof the yeast at least an hour in advance. In addition, the suspension should be placed on a stir plate and students should pull samples from the middle of the suspension. Our resident biologists have revisited this experiment and found that purified catalase enzyme can be substituted for the yeast suspension in this exercise. This is an excellent option for investigating the effect of enzyme concentration. This is also a very cost-effective solution, as 1 g of catalase will provide enough enzyme for more than 4000 trials!



Oxygen gas production during "Testing Catalase Activity" investigation

- Purified catalase enzyme can be purchased from Flinn Scientific, Ward's Natural Science, or Sigma-Aldrich. The concentration of enzyme varies from 2000–5000 units/mg and depends on the bottle.
- You can mix up a stock solution of the enzyme in water. Make a stock solution of 1000 units/1 mL. For a step-by-step video on how to do this, visit Flinn's web site, www.flinnsci.com/catalasevideo
- If you are using the O_2 Gas Sensor for this investigation, use 0.5 mL (5 drops) of 1000 units/1 mL catalase solution for the preliminary activity. Add the enzyme to a 250 mL Nalgene bottle first, then add 10 mL of 3% H_2O_2. Start data collection immediately.
- If you are using the Gas Pressure Sensor for this investigation, use 1 drop of 200 units/mL catalase for the preliminary activity. Add the enzyme to a 20 mL test tube or 15 mL conical tube first, then add 6 mL of 3% H_2O_2. Start data collection immediately.
- If students are investigating enzyme concentration as an independent variable, make 100 units/mL, 1000 units/mL, and 2000 units/mL enzyme solutions.
- If students are investigating substrate concentration, start with 6% H_2O_2 instead of 3% H_2O_2. This can be ordered from Flinn Scientific, Ward's Natural Science, or Sigma-Aldrich.
- Store the catalase powder as instructed. Enzyme activity may decrease from year to year, but will remain viable for up to three years.

By using these tips, you and your students will have greater success in your inquiry investigations on catalase. Download the "Testing Catalase Activity" investigation at www.vernier.com/bio-i

BIOLOGY

New Goniometer Increases Options for Human Physiology Experiments

Vernier's newest addition to our human physiology offerings is the Goniometer. The Goniometer measures the angle of a joint, such as the knee or elbow. A set of elastic straps are used to secure the sensor to the subject for dynamic measurements of joint angle during physical activity, such as walking, running, and cycling. You can also use the Goniometer with a Vernier EKG Sensor to measure muscle activity during different phases of limb motion. In addition, this sensor can be used in STEM and engineering activities. This versatile sensor is a great addition to your Vernier physiology sensors.

GNM-BTA, $159

Using the Goniometer to Measure the Height of Trees

Vernier and Oregon Forest Resources Institute team up to encourage teachers to Leave No Child Inside

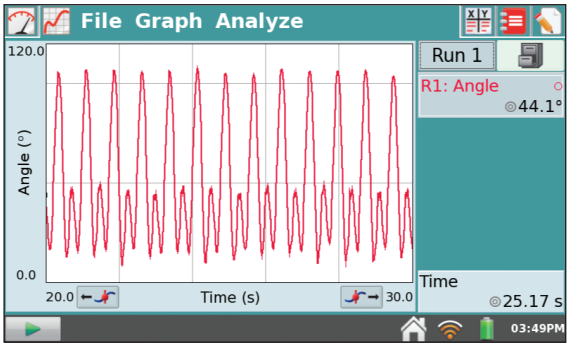
LabQuest 2 was the star of the show at a Fieldwork Workshop hosted by the Oregon Forest Resources Institute at the Oregon Garden in Silverton, OR, on a drizzly February day. The workshop highlighted how teachers could get outside and collect data with their students.

Teachers used the Goniometer in an innovative way to measure the height of trees in the Rediscovery Forest at the Oregon Garden. Using the LabQuest 2 in Events with Entry mode, teachers manually entered data in conjunction with recorded data. LabQuest 2 and the Goniometer were used to determine the angle to the top of the tree, calculate the tree height, and record GPS coordinates for later export to a map.

To download the "Finding Tree Height and Diameter" investigation, along with the LabQuest files, go to www.vernier.com/r138

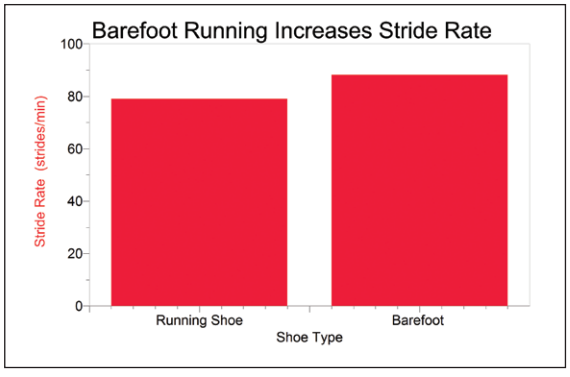
Analysis of Barefoot Running

John Melville, our Biology Staff Scientist, has found that our new Goniometer is a great sensor for investigating running. As shown in the sample data below, students can use a LabQuest and the Goniometer to record joint angle data from the knee while running. The running waveform contains both a large and a small peak. Full flexion of the knee occurs at the large peak. The small peak coincides with the landing of the foot.



Joint angle data from the knee while running

With this in mind, we have developed a new experiment, "Analysis of Barefoot Running." In this experiment, students use the Goniometer to investigate the biomechanics of barefoot running, a new running trend popularized by Christopher McDougall in the book *Born to Run*. Traditional running technique emphasizes a heel-to-toe foot strike during each stride. Without the padding provided by traditional running shoes, barefoot running tends to minimize heel strike. This leads to an increase in stride rate, or cadence, of the barefoot runner. As shown in the data below, barefoot running leads to an increase in John's stride rate when he runs barefoot. You can download this exercise and several other new experiments that use the Goniometer at www.vernier.com/gnm-bta



Comparison of stride rate when wearing shoes or running barefoot

SOFTWARE

Software Updates

We regularly release software updates to support new sensors, as well as to add new features. Keeping up to date with software releases is one way to keep things running smoothly in your classroom or lab. Have you updated your Vernier applications recently?

LOGGER *PRO* 3.8.6.1

Logger *Pro* 3.8.6.1 will be released in April 2013. We recommend that all users of Logger *Pro* update to this release. This update is free to all users of any previous version of Logger *Pro* 3, and is available at www.vernier.com/lpupdates

The new version improves video analysis features, makes numeric entry more robust, and updates numerous experiment files. Google Maps export is updated for compatibility with changes at Google and exports large data sets more reliably.

Of particular note in this version is updated support for the Connected Science System. Logger *Pro* can share sensor data with Graphical Analysis for iOS. It can also share data using the Vernier Data Share web app in any device running a modern browser. Version 3.8.6.1 includes an updated version of the service, improving speed, stability, and usability.

With an account on the Vernier web site and a purchase history of Logger *Pro*, you can download the full installer at any time—no waiting for a CD or download link. To create an account go to www.vernier.com/account/

The next planned release for Logger *Pro* is in the third quarter of 2013.

LABQUEST 2.2

LabQuest 2.2 for LabQuest 2 will be released in April 2013. Version 2.2 adds the Pivot Data feature for more flexibility in graphing while in the Data Matrix mode, as well as new calculated columns for digital filtering. New drivers improve Wi-Fi connection stability and new connections screens simplify connecting to the desired Wi-Fi network. Better power management improves battery life. The Vernier Data Share web app has been enhanced, improving speed, stability, and usability. Graph export has been substantially improved.

Note that the previous 2.1 release added support for Enterprise Wi-Fi networks, or those with username/password combinations.

We recommend that all users of LabQuest 2 update to this release. This free update to LabQuest 2 is available at www.vernier.com/lq2updates

LABQUEST 1.7

LabQuest 1.7 for the original LabQuest hardware was released in September 2012. Version 1.7 adds support for newly released sensors and improves graphing for spectrometers. This free update is available at www.vernier.com/lqupdates

LOGGER LITE 1.6

Logger Lite 1.6 was released in April 2012 to support LabQuest 2. The previous release of Logger Lite added support for LabQuest Mini and Windows 7 (including 64-bit machines), as well as linear fits. The free update is available at www.vernier.com/llupdates

VIDEO PHYSICS FOR iOS

The current version of Video Physics is 1.2, updated in December 2012. This version adds the important ability to export video analysis data to Graphical Analysis for iOS. Once in Graphical Analysis, you can perform selections, add annotations, perform curve fits, and create high-resolution graphs.

Updates to Video Physics are free and are available in the App Store.

GRAPHICAL ANALYSIS FOR iOS

An update to Graphical Analysis for iOS, 1.4, will be released in the App Store shortly. For this update, we have focused on making the app easier to use and easier to learn. A QR code scanner makes it easy to connect to LabQuest. Updates to Graphical Analysis for iOS are always free and are available in the Apple App Store.

APPLE VOLUME PURCHASE PROGRAM

Purchasing apps for iOS devices can be a challenge for schools. Did you know that your school or department can purchase vouchers to distribute apps such as Vernier Video Physics to multiple devices?

This is a way to distribute iOS apps to both school-owned and student devices. You can use purchase orders or a credit card, and school purchases are tax exempt. You receive a 50% discount when purchasing 20 or more copies of Vernier Video Physics or Vernier Graphical Analysis from the App Store. www.apple.com/itunes/education/

SOFTWARE

NEW Using Logger *Pro* 3 with iPad and Mobile Devices *(continued from cover)*

the installation process. Because Logger *Pro* is the Data Sharing source, you can use a LabPro, original LabQuest, LabQuest Mini, or even a Go!Link to share data with an iPad or other tablet. Your existing computers, interfaces, and sensors can all work with the latest devices.

With Data Sharing enabled, Logger *Pro* 3 can share data using the Vernier Data Share web app, allowing students to use a compatible web browser, such as Safari or Chrome, to wirelessly collect, view, and analyze sensor data. Most Android tablets, smartphones, the iPod touch, and even other computers will work with Logger *Pro.* Point your browser to Logger *Pro*, and see your own graph of the current data. Rescale, perform curve fits, and do other analysis on your own without affecting the graphs or data on Logger *Pro.*

Interested in a native iPad app? Graphical Analysis for iOS, which sells for $4.99 in the Apple App Store, can receive data from Logger *Pro* on your iPad. Once on the iPad, the data can be analyzed and studied independently of what's going on with the data on the computer. Graphical Analysis can store experiments for later analysis, so students can collect data from several sources and then work on analysis later.

Logger *Pro* 3 with Data Sharing enabled gives you new options for getting data in your students' hands. But, there are other cool things you can do with the Vernier Data Sharing feature and Logger *Pro*:

- Share data from your demo with a whole classroom. Students can analyze data individually or in small groups, all on their own devices. This is perfect for interactive engagement or flipped classrooms.
- Share any lab group's data with the whole class. Did group three do something awesome? Project it to the class by viewing the data in a browser on your instructor computer.
- Monitor a long experiment in the basement—no need to go check on it.

Of course, LabQuest 2 can also serve as a Data Sharing source and share data in the same way.

Data Sharing requires a Wi-Fi network that can be joined by both the computer or LabQuest 2 sharing data and the students' devices. For more details on network requirements, see our user manuals at www.vernier.com/r139

1:1 Learning with the iPad and the Connected Science System®

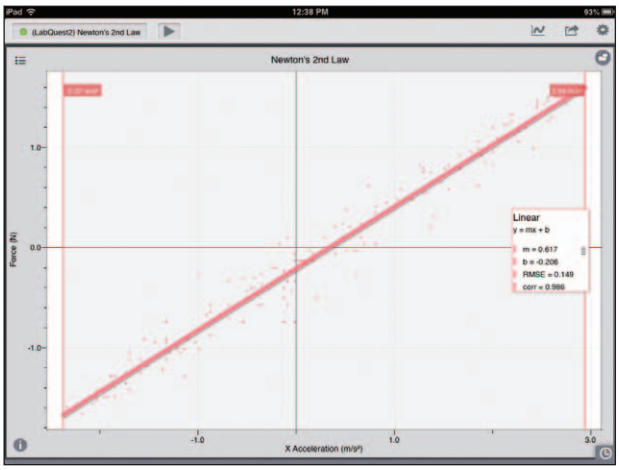
by Matt Anthes-Washburn

Earlier this year Jesuit High School, in Portland, OR, began investigating ways to use technology to engage students across the curriculum and to introduce personalized learning at a low cost. After evaluating the available technologies, physics teacher, Jennifer Cournia, chose the Connected Science System for use in her honors physics class. Using LabQuest 2 and the school's existing sensors, each lab group was able to work together on an experiment while wirelessly streaming data to Graphical Analysis on the iPad.

In the investigation "Newton's Second Law" from *Physics with Vernier*, students mounted a Low-g Accelerometer and Dual-Range Force Sensor to a Vernier Dynamics cart. As students pushed and pulled the cart on the track, the force applied and the resulting acceleration data were recorded. The data were wirelessly streamed over the school's Wi-Fi network from LabQuest 2 to the Graphical Analysis app, where they completed their analysis individually.

Students investigated the force *vs.* time and acceleration *vs.* time graphs in Graphical Analysis and immediately noticed a relationship: data points with a large positive force also had a large positive acceleration. A large negative force yielded a large negative acceleration.

To investigate the relationship between force and acceleration, students made predictions about the shape of a force *vs.* acceleration graph. Next, each student set up the axes of that graph in Graphical Analysis and applied a linear fit. Students discovered that the slope, or force per acceleration, corresponded to the combined mass of the cart and sensors.



Students study the relationship between the force and acceleration of a dynamics cart. A linear fit shows that the relationship is proportional.

To finish up the lab, students used the export function in Graphical Analysis to submit their graphs to a course management app, where Ms. Cournia had the tools to review, grade, and comment on students' work.

As students' comfort with using the iPad and lab equipment grows, Ms. Cournia hopes to gather increasingly valuable insights on student understanding. Students will annotate their graphs, combine it with their lab reports in Pages®, and submit it instantly for assessment. Ms. Cournia will be able to gauge student understanding, as it develops, and adjust her instruction accordingly. The combination of mobile technology with LabQuest 2 and Vernier probeware provides new opportunities for student engagement.

Price of Original LabQuest Dropped to $299

Now is the time to add to your collection of original LabQuests! We have reduced the price of the original LabQuest (order code LABQ) to $299. The LabQuest 2 sells for $329. www.vernier.com/labq

~~$329~~

ORDER CODE
LABQ

$299

Temperature Probe sold separately.

VERNIER AWARDS

Vernier is proud to be recognized for its philanthropic commitment, steady growth, and as one of the Best 100 Companies to Work For in Oregon—for 13 years in a row.

INTERNATIONAL AWARD FOR LABQUEST

BUSINESS JOURNAL CORPORATE PHILANTHROPY AWARD

FASTEST GROWING PRIVATE COMPANIES

PLACED 16TH OF 100 BEST GREEN COMPANIES IN OREGON

2012 HEALTHIEST EMPLOYERS 5TH PLACE

HALL OF FAME OREGON BUSINESS AWARD

NSTA Reviews Vernier Technology

Want to know what your fellow science educators think about Vernier technology? The National Science Teachers Association classroom tested and reviewed LabQuest 2, Logger *Pro*, and a Go!Motion Sensor.

The Science Teacher, January 2013
"In summary, the LabQuest 2 from Vernier is an outstanding tool to engage students in scientific inquiry. In my opinion, its reasonable price and ease of use make the LabQuest 2 a valuable tool for students conducting scientific investigations. It can help motivate them toward greater science achievement. If you're interested in a versatile and cost-effective tool that is user friendly, look no further than Vernier's LabQuest 2." – Edwin Christmann

Science Scope, January 2013
"Between the interface to the software and the number of possible applications, this is one of the most modular and versatile tools of scientific investigation a physics teacher is likely to encounter... I must admit a large part of what makes the Go! Motion sensor a great piece of lab equipment is the software. Logger *Pro* is intuitive, straightforward, and inexpensive." – Seth Guiañals-Kupperman

JOB OPENINGS AT VERNIER

Vernier's Biology and Physics Departments each have a job opening. If you want to help shape the future of biology or physics at Vernier, apply for one of our Educational Technology Specialist positions. We are looking for people who are currently teaching or have recently taught biology or physics using Vernier products; experience teaching AP/IB Biology or AP/IB Physics is desirable. Vernier has been one of the "100 Best Companies to Work for in Oregon" for 13 years in a row. Vernier Software & Technology is an Equal Opportunity and Affirmative Action Employer.

Application deadline is May 6, 2013. For details, visit www.vernier.com/jobs

NEW Vernier Optical DO Probe *(continued from cover)*

The body of the probe is waterproof and can be submerged up to 1.6 m, allowing students to take direct measurements in the field. Attach the Optical DO Probe Metal Guard (order code ODO-GRD, $45) to protect the cap and to help weigh down the probe.

Looking for experiments? Several dissolved oxygen experiments are available from Vernier lab books such as *Biology with Vernier, Water Quality with Vernier*, and *Investigating Environmental Science through Inquiry*. The sample data collected using the Optical DO Probe shows the temperature dependence of dissolved oxygen as written in Experiment 19 from *Biology with Vernier*.

For more information visit www.vernier.com/odo-bta or contact technical support at support@vernier.com

Vernier/NSTA Technology Award Winners Announced

Recipients each win $5,500 in cash and technology

Co-sponsored by Vernier and NSTA, The Vernier/NSTA Technology Awards recognizes educators for their innovative use of data collection. Christine and David Vernier will present each of this year's winners with their awards at the NSTA convention in San Antonio. Each winner receives $1000 in cash, $3000 in Vernier technology, and $1500 towards expenses to attend the convention. Below are brief synopses for the 2013 award-winning entries.

CATEGORY: MIDDLE SCHOOL

Christine Herald
Eisenhower Middle School, Manhattan, KS

Herald introduces her students to technology through science exploration. With this award, Herald will add pH Sensors to her "Easy Bake Oven® Heat Transfer Lab," which investigates the pH of different cakes and chemical reactions. She will also add Light Sensors for physics investigations, as well as Temperature Probes for various investigations.

Kristy Schneider
La Center Middle School, La Center, WA

Schneider's electronics engineering class works alongside a local scientist to create control boxes for underwater remotely-operated vehicles (ROVs). As part of her winning project, students will extend their understanding of engineering concepts by using Vernier sensors with LabQuest 2 to conduct water-quality tests at nearby wetlands with their ROVs.

CATEGORY: HIGH SCHOOL

Cara Hale-Hanes
Long Beach Polytechnic High School
Long Beach, CA

Hale-Hanes challenges students to solve real-world chemistry problems through her investigation, "Design a Biological Buffer for Water Treatment." Based on the World Water Monitoring project that delivers potable water to people around the world, students will use the Vernier pH Sensor with LabQuest and software to test their selected buffers.

Crystal Sengstaken
The Archer School for Girls, Los Angeles, CA

Seniors in Sengstaken's System Biology and Disease course gain an understanding of body structure and function in health and disease through technology-based projects. After studying the anatomy and physiology of the muscular system, students design their own experiment utilizing the Vernier EKG Sensor to investigate muscle function and neuromuscular reflexes.

Darrell Coston
Goldsboro High School, Goldsboro, NC

In "The Effects of UV Radiation on Bacterial Cell Growth," Coston's chemistry students utilize Cell Theory with a variety of Vernier sensors to conduct an inquiry-based investigation of UV radiation and its effects on cellular growth. Students learn sterile laboratory techniques and gain an understanding of the effects of environmental radiation.

Katherine Schenkelberg
West High School, Torrance, CA

Schenkelberg is transforming her Muscular System Unit to include more data-collection technology and Common Core practices for students to research and present practical applications of learned concepts. Her anatomy and physiology students will complete a series of data-collection inquiry labs using Vernier's EKG Sensor and Hand Dynamometer to investigate the electromyogram (EMG).

CATEGORY: COLLEGE

Heidi Bulfer
Colby Community College, Colby, KS

As the only biology teacher at her college, Bulfer designs labs that solidify biological principles and encourage students to extend their knowledge through real-world application. Bulfer will expand Vernier's "Photosynthesis and Respiration" experiment to investigate photosynthesis and respiration rates of different agricultural crops grown in northwest Kansas, home of the college.

Interested in submitting an application of your own?

Applications are due November 30, 2013.
www.vernier.com/grants/nsta

SCIENCE HUMOR

This time we have one joke for each of the three major science branches: physics, biology, and chemistry.

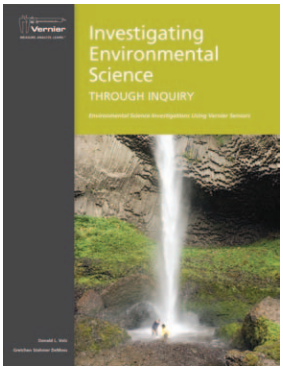
PHYSICS A photon walks into hotel. Bellhop: "Need help?" Photon: "Nope—I'm traveling light."

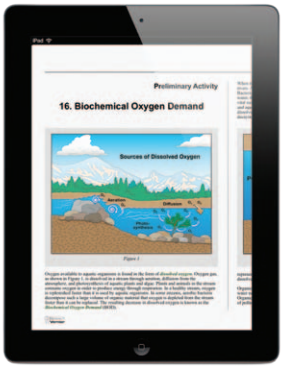
BIOLOGY What do you call a Drosophila who likes to drink? A bar fly.

CHEMISTRY I told a chemistry joke, but there was no reaction.

Investigating Environmental Science through Inquiry iBook now available

This popular lab book is now available for iPad on the iBookstore. This student companion to the print version contains student instructions, a new glossary feature, and images in full color. www.vernier.com/products/books/esi





NEW Instructional Videos Now Available in Our Video Training Library

Need help calibrating your Ion-Selective Electrodes or updating your LabQuest? Our team of technology specialists spent the winter developing more videos to help you with your sensors. In addition to our Tech Tips videos, there are new videos for experiments with the Vernier Radiation Monitor and the EKG Sensor. For more information, visit www.vernier.com/latest-videos

TECH TIPS

- Anemometer
- Centripetal Force Apparatus
- CO_2 Gas Sensor
- Current Probe
- EKG Traces
- Extra-Long Temperature Probe
- Force Plate
- Goniometer
- GPS with LabQuest 2
- Hand Grip Heart Rate Monitor
- Infrared Thermometer
- Ion-Selective Electrodes
- LabQuest Software Updates
- Motion Detector
- Pyranometer
- Respiration Monitor Belt
- Soil Moisture Sensor
- Surface Temperature Sensor
- Thermocouple
- UV Sensors
- Vernier Projectile Launcher
- Vernier Radiation Monitor
- Watts Up Pro
- Wireless Dynamics Sensor System

EXPERIMENTS

- Counting Statistics with the Vernier Radiation Monitor
- EMG and Muscle Fatigue

ENGINEERING PROJECTS

- Using the Digital Control Unit with Logger *Pro*
- Engineering Projects with Vernier, PID Systems

AAPT and NSTA in Portland

Plan your trip to Portland, Oregon

Two important conferences are coming to our home town of Portland:

- American Association of Physics Teachers (AAPT) July 13-17, 2013
- National Science Teachers Association (NSTA) Western Regional October 24-26, 2013

We will be sponsoring activities at both of these conferences, and we will offer tours of our office. There will be gifts for everyone who visits.

NEW TI-84 Plus C Silver Edition is now Available

The TI-84 Plus C Silver Edition has a full-color, high-resolution, backlit screen, making it easy to read and offers a seamless transition from a TI-83/84 with the same menu structures, navigation, and applications. Deepen student understanding with Vernier EasyData 4.0 for data collection with 63 Vernier sensors to investigate concepts in math and science. The calculator comes with a rechargeable battery, so there is never a need to buy AAA batteries. The TI-84 Plus C Silver Edition is also available in a Teacher Pack of 10 handhelds that includes 10 EZ-Spot calculators and a 10 unit charging station. Note: TI-84C cannot be used with TI-Navigator systems.

A full list of features and more information can be found at www.vernier.com/ti-84c

TI-84 Plus C Silver Edition, TI-84C, $129
TI-84 Plus C Teacher Pack, TI-84C-TPK, $1,345

PROFESSIONAL DEVELOPMENT

Free Hands-On Data-Collection Workshops

Calling all science educators! Join us for a four-hour exploration of the latest and greatest in Vernier probeware and data-collection technology. You will conduct hands-on experiments using various sensors with the LabQuest 2 interface or on a computer.

PERFECT FOR SCIENCE EDUCATORS WHO:

- Want to evaluate our award-winning technology
- Are new to data collection
- Need a refresher course on Vernier equipment
- Want to learn from an expert

ATTENDEES RECEIVE:

- Four hours of free training
- Light lunch or dinner
- Workshop Training Manual
- Savings on a workshop package

APRIL

18	Richmond, VA
20	Arlington, VA
22	Baltimore, MD
22	Baton Rouge, LA
23	Dover, DE
23	Jackson, MS
24	Little Rock, AR
24	San Jose, CA
25	Memphis, TN
25	San Francisco, CA
27	Stockton, CA
30	Pasadena, CA
30	Philadelphia, PA

MAY

1	Riverside, CA
1	Princeton, NJ
2	Newark, NJ
4	Stamford, CT

Chautauqua Short Course: *Research-Based Active Learning in Introductory Physics*

NEW: Including RealTime Physics 3rd Edition, Clicker Interactive Lecture Demos, and Video Analysis

June 21–23, 2013, Portland, Oregon

This course is designed for those who teach introductory physics at universities, colleges, and high schools. Graduate credit will be available.

Instructors: Priscilla Laws, Dickinson College, David Sokoloff, University of Oregon, Ronald Thornton, Tufts University

This hands-on course is designed for those interested in making learning in their introductory course more active, either within a traditional course structure (lectures, labs, and recitation hours), or by re-structuring their course (e.g., into a workshop or studio course).

For more information on the course and to register visit http://pages.uoregon.edu/sokoloff/CHAUT.htm

Hands-On Summer Institutes

School may be out for the summer, but the learning never stops at Vernier. Join us for a full-day exploration of Vernier's award-winning line of computer and handheld data-acquisition technology. You'll leave the workshop ready to excite your students' learning with data collection.

The cost of the institute is $99, which includes a lab book of your choice (a $48 value). Please see the web site for Training Package pricing. The registration form can be found at www.vernier.com/training/summer-institutes/

JUNE

11	Atlanta, GA
13	Nashville, TN
17	St. Louis, MO
19	Kansas City, MO
21	Wichita, KS
21	Phoenix, AZ
24	Denver, CO
24	Albuquerque, NM
26	Cheyenne, WY
26	Amarillo, TX
28	Salt Lake City, UT

JULY

8	Houston, TX
8	Fairfax County, VA
10	Dallas, TX
10	Philadelphia, PA
12	Oklahoma City, OK
12	Hartford, CT
22	Pittsburgh, PA
22	Milwaukee, WI
24	Columbus, OH
24	Chicago, IL
26	Indianapolis, IN
26	Detroit, MI

AUGUST

14	Beaverton, OR
16	Seattle, WA

Modeling Workshops at Arizona State University

Arizona State University in Tempe invites high school physics, chemistry, and physical science teachers nationwide to enroll in its summer 2013 Modeling Workshops. Modeling Workshops thoroughly address many aspects of high school science teaching, including strategies for integrating model-centered, guided inquiry teaching methods with course content. Workshops incorporate up-to-date results of physics and science education research, sample high school curricular materials, hands-on use of technology, and experience in collaborative learning. For more information and specific site dates, please visit www.vernier.com/training/independent/

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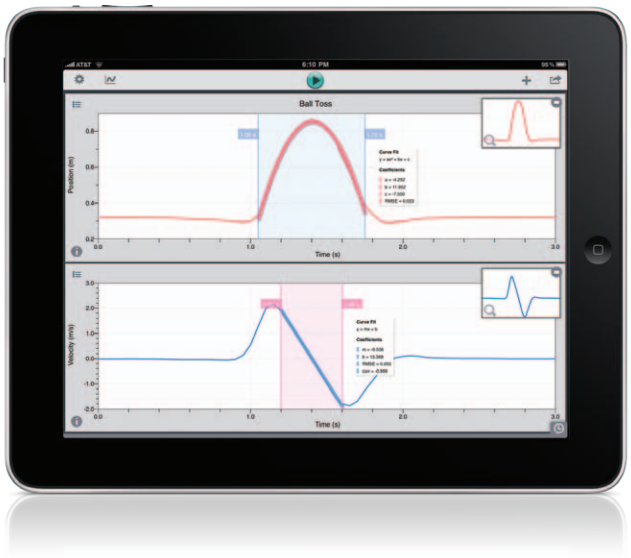
Gear Up for iPad® Data Collection

vernier.com/ipad



LabQuest® 2
Collect and analyze data with iPad and other mobile devices.
www.vernier.com/labquest2

Graphical Analysis™ for iPad
Download this iPad app to collect, analyze, and annotate data.
www.vernier.com/ga-ipad

Video Physics
Record video and analyze motion frame by frame.
www.vernier.com/videophysics