

The Metric Backpack

I greatly prefer the elegant, simple, easy-to-learn and -teach metric system to the klutzy, complicated, hard-to-learn and -teach U.S. Common System of units.

—Laran Stardrake



*By Bob Albrecht
and Paul Davis*

Subject: Science, math

Audience: Teachers, teacher educators

Grade Level: 5–12 (Ages 10–18)

Technology: Internet, Web

Standards: NETS•S 3; NETS•T II
(www.iste.org/standards)

Measurement is a big chunk of the foundation of science, applied mathematics, engineering, and other areas of human endeavor. On Gaia today, two systems of measurement are used. One is the International System (SI) of units, commonly called the metric system. It is well designed, easy to learn, easy to use, and used everywhere on Gaia except in one country. The other system is the United States Common System (USCS). It has been kludged together over many centuries, is poorly designed, hard to learn, hard to use, and used in only one country—the United States of America.

Yes, that's the bad news. The United States is the only country in the world not using the metric system for ordinary everyday measurements. But there is good news. U.S. scientists joined the rest of the world and went metric long ago. Science courses, science textbooks, and scientific literature use metric units. Enlightened teachers teach metric measurement in math and science from about third grade on. National math and science standards encourage teaching metric measurement.

We encourage you to visit the National Council of Teachers of Mathematics (NCTM) Web site and read its position statements on metrication. (*Editor's note:* Find this and other URLs under Resources at the end of this article.) For example:

- The NCTM recommends the use of the metric system as the primary measurement system in mathematics instruction.
- Measurement is a common daily activity performed throughout the world and in all sectors of society. As a well-conceived, logical system of units, the metric system provides

models that reinforce concepts and skills involving numeration, decimal relationships, and estimation, connecting mathematics to the rest of the PK–12 curriculum.

- On an international level in the scientific and industrial worlds, the metric system is the standard system of measurement. Canada adopted the metric system long ago and immediately mandated that all school curricula use the metric system exclusively. To compete in a world that already functions with this system, our students also need to be competent with the metric system.
- Given that the English customary system (NCTM's name for the USCS) is well established in the United States and that the metric system is used throughout the rest of the world, the PK–12 curriculum should include both systems.
- All mathematics educators should assume responsibility for providing leadership and direction in metrication by integrating it into the entire curriculum at every grade level.

As our tiny contribution to metric evangelism, we are developing *Metric Backpack*, a collection of tools and toys to help learners learn and teachers teach the metric system. Metric Backpack is an introduction to the SI. It contains information from A to Z about:

- Le Système International d'Unités (SI).
- The U.S. Common System of Units (USCS).
- Units used in science, math, and everyday life.
- Internet sites that contain relevant information, tutorials, lesson plans, and whatever else strikes our fancy.
- Our original instructional activities.

We'll share as much stuff from Metric Backpack as we can cram into our column. Let's begin with fundamental information and Internet links about the SI.

The International System of Units

World headquarters for the SI is at the Bureau International des Poids et Mesures (BIPM) in France. You can go to BIPM's Web site and select the English or French language versions. If you are studying French, this is a splendid opportunity to get some reading practice. French is Greek to us, so we clicked on "Continue in English" and went to BIPM Welcome. Here, you can click on "International System of Units (SI)."

The same information resides in the United States at the National Institute of Standards and Technology (NIST). Go to International System of Units from NIST. From this site, you can link to many other pages. For example, the "Essentials of the SI: SI units and prefixes" lists the seven SI *base units* (meter, kilogram, second, ampere, kelvin, mole, and candela) and examples of SI *derived units* (area, volume, speed, et cetera). To save you a trip, we list the seven base units in Table 1 and a few derived units in Table 2.

People doing history investigations can read the brief histories of the metric system from the time of the French Revolution to recent times at the history section of the NIST Web site. For more historical information about the seven base units, click on the name of the unit under the heading "Historical context of the SI."

We also enjoyed reading a different view of metric history in an online article at the Applied Technology

Table 1. SI Base Units

Base quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Table 2. SI Derived Units

Derived quantity	Name	Symbol
area	square meter	m ²
volume	cubic meter	m ³
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s ²
mass density	kilogram per cubic meter	kg/m ³

Institute's Web site—"The International System of Units: Its History and Use in Science and Industry," by Robert A. Nelson.

If you want to convert quantities between the USCS and the SI systems, you'll find links to online unit conversions on the NIST site. We like the WWW Unit Converter and the Megaconverter 2.

You can read SI publications online or order paper versions: books, booklets, charts, and such. You can order a free copy of NIST Special Publication 811: *Guide for the Use of the International System of Units* by Barry N. Taylor (1995) or download it online and read it using Adobe Acrobat Reader.

Would you like a handy little book to stuff into your backpack? We recommend *Measurements & Conversions: A Complete Guide* (1994).

- Dimensions: 8.0 cm x 11.7 cm x 1.2 cm
- Volume: (8.0 cm)(11.7 cm)(1.2 cm) = 110 cm³ [2 significant digits]
- Mass: 87.3 g
- Price: \$5.95
- Price per gram: (\$5.95)/(87.3 g) = 0.0682 \$/g

We searched the Internet for lesson plans using the Google search engine

with the keywords: "lesson plan" metric. Google found more than 2,000 lesson plans. We looked at the first 30 and bookmarked these:

- Metric System Lesson Plan
- Grades 4–6 Science Lesson Plan

Metric Tools and Toys

The next time or two we'll talk about the basic physical quantities length and mass, and the derived quantities: area, volume, and mass density. We'll use these units (basic units are in bold-face type):

- Length: millimeter, centimeter, **meter**, kilometer
- Mass: milligram, gram, **kilogram**
- Area: square centimeter, square meter
- Volume: cubic centimeter, cubic meter, milliliter, liter
- Mass density: grams per cubic centimeter, kilograms per cubic meter

We've collected a bunch of tools to stuff into our metric backpack. To measure lengths of small things, we use a Vernier caliper (Figure 1). For the Metric Backpack activities that we'll describe in upcoming issues, Nasco's \$5.90 Vernier caliper works well. Look for it at Nasco's Web Store, eNASCO Online Catalogs. Boggled by Vernier calipers?



Figure 1. Vernier caliper (from Nasco).



Figure 2. Windup tape (from Nasco).

Learn what they are and how to use them at the Vernier Calipers Lesson Page, the Measurements Lab, and the Java Applet—Vernier sites.

For measuring larger objects, metric rulers are the right stuff. We trust that you already have them in your classroom. We use 15-centimeter rulers, 30-centimeter rulers, and meter sticks. As compulsive collectors of measurement tools and toys, we also have tape measures (Figure 2) in various lengths, including the following from Nasco:

- Retractable tape measure, 1.5 meters (150 centimeters), \$3.35
- Windup tape measure, 10 meters, \$9
- Windup tape measure, 30 meters, \$16.95

A trundle wheel (Figure 3) is an appropriate tool for measuring distances in the schoolyard, around town, or on a hiking trail—and fun for kids to use. A trundle wheel is a wheel on a stick. To measure the distance from here to there, you start here and push the trundle wheel there. Every time the wheel goes around completely, you hear a click. Each click is one meter. Count the clicks and you'll know the distance from here to there. Our low-budget eye is looking at \$20 trundle wheels in school catalogs. We frequently day-



Figure 3. Trundle wheel (from Nasco).

dream while trundling from here to there and tend to forget the count, so we yearn for a distance measuring wheel in the Forestry Suppliers catalog online. These beauties have counters that count the number of wheel turns, but they run a bit closer to \$100 (or more, if you go digital). Definitely the right stuff for walking, daydreaming, and measuring the distance you meander.

Area is a derived quantity measured in square units of length such as square centimeters or square meters. You can calculate areas of squares, rectangles, triangles, circles, and other shapes by measuring them with a ruler or Vernier caliper and using appropriate equations to get the area. We'll explore other ways to obtain areas.

Volume is a derived quantity measured in cubic units of length such as cubic centimeters or cubic meters. The volume of a liquid may also be measured in liters or milliliters using beakers (Figure 4) and graduated cylinders (Figure 5). You can calculate volumes of cubes, rectangular parallelepipeds, spheres, and other objects by measuring them with a ruler, tape measure, or Vernier caliper and using appropriate equations to get the volume. We'll explore other ways to obtain volumes.



Figure 4. Beakers (from Nasco).

Mass is a fundamental physical quantity. It is the quantity of matter in the object. Mass is a measure of an object's inertia, its resistance to a force applied to the mass in an effort to change its state of motion. If you look up *mass* and *matter* in a dictionary, you may find that they are defined in terms of each other, thus completing a circular definition. The SI unit for mass is the kilogram (kg). To measure mass, we use these tools:

- Equal-beam balance (Figure 6)
- Triple-beam balance (Figure 7)
- Electronic balance (Figure 8)

Density is a measure of the amount of mass contained in a unit volume. The density of an object is the mass per unit volume of the object, usually expressed in grams per cubic centimeter or kilograms per cubic meter. To calculate the density of an object, use a balance to get its mass, calculate its volume, and divide the object's mass by its volume:

$$\text{density} = \text{mass/volume or } d = m/v$$

In future issues, we'll describe or suggest measurement activities using objects such as base-10 blocks, balls, BBs, beans, buttons, candy, cans, corks, Cuisenaire rods, cylinders, dollar bills,

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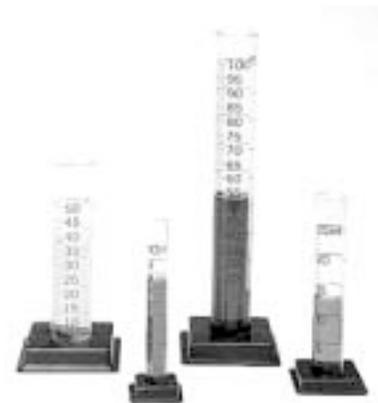


Figure 5. Graduated cylinders (from Nasco).



Figure 6. Equal-arm balance (from Nasco).



Figure 7. Triple-beam balance (from Nasco).



Figure 8. Electronic balance (from Nasco).

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lumpy things, machine screws and nuts, marbles, nails, paper clips, pattern blocks, coins, pins, rope, sinkers, staples, steel ball bearings, Styrofoam spheres, thumbtacks, washers, wooden spheres, and whatever else we think about between now and then.

Resources

Articles & Books

“The International System of Units: Its History and Use in Science and Industry,” by Robert A. Nelson: www.atcourses.com/international_system_units.htm

Measurements & Conversions: A Complete Guide (1994) The Diagram Group, Running Press Book Publishers: www.runningpress.com

Lessons

Measurements Lab: <http://post.uwstout.edu/k/kernm/measurelab.html>

Metric System Lesson Plan: www.usd.edu/~msemmler/metricsystem.html

Grades 4–6 Science Lesson Plan: www.k-6educators.about.com/library/lp/blpsci46a.htm

Java Applet—Vernier: www.phy.ntnu.edu.tw/~hwang/ruler/vernier.html

National Institute of Standards and Technology (NIST): <http://physics.nist.gov>
NIST history section: <http://physics.nist.gov/cuu/Units/history.html>
NIST International System of Units: <http://physics.nist.gov/cuu/Units/index.html>
NIST Special Publication 811: *Guide for the Use of the International System of Units* by Barry N. Taylor (1995): <http://physics.nist.gov/cuu/Units/bibliography.html>

NIST unit conversions: <http://physics.nist.gov/cuu/Reference/unitconversions.html>

Vernier Calipers Lesson Page: <http://regentsprep.org/Regents/math/tools/vernier.htm>

Supplies

eNASCO Online Catalogs: www.enasco.com

Forestry Suppliers catalog: www.forestry-suppliers.com

Pollard Water: www.pollardwater.com/emarker+/PagesL2500027scale.asp

Web Sites

Bureau International des Poids et Mesures: www.bipm.fr

Google: www.google.com

Megaconverter 2: www.megaconverter.com/mega2

National Council of Teachers of Mathematics: www.nctm.org/about/position_statements/position_statement_09.htm

WWW Unit Converter: www.digitaldutch.com/unitconverter



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Laran Stardrake, whose quotes sometimes lead off this column, is another of Bob's "accomplices." She's half dragon and half human. As Laran is fond of saying, "Reality expands to fill the available fantasies." The DragonFun image is from an original painting by Marcy Kier-Hawthorne.



Paul Davis (ctec1@mchs.srca.k12.ca.us) is a mathematics teacher at Maria Carrillo High School in Santa Rosa, California. He was a happy, normal teacher until he met Bob Albrecht and George

Firedrake in 1992 and became another one of their accomplices. Since then, Paul has been intertwining math, science, and technology in his classroom with the help of Bob and George.