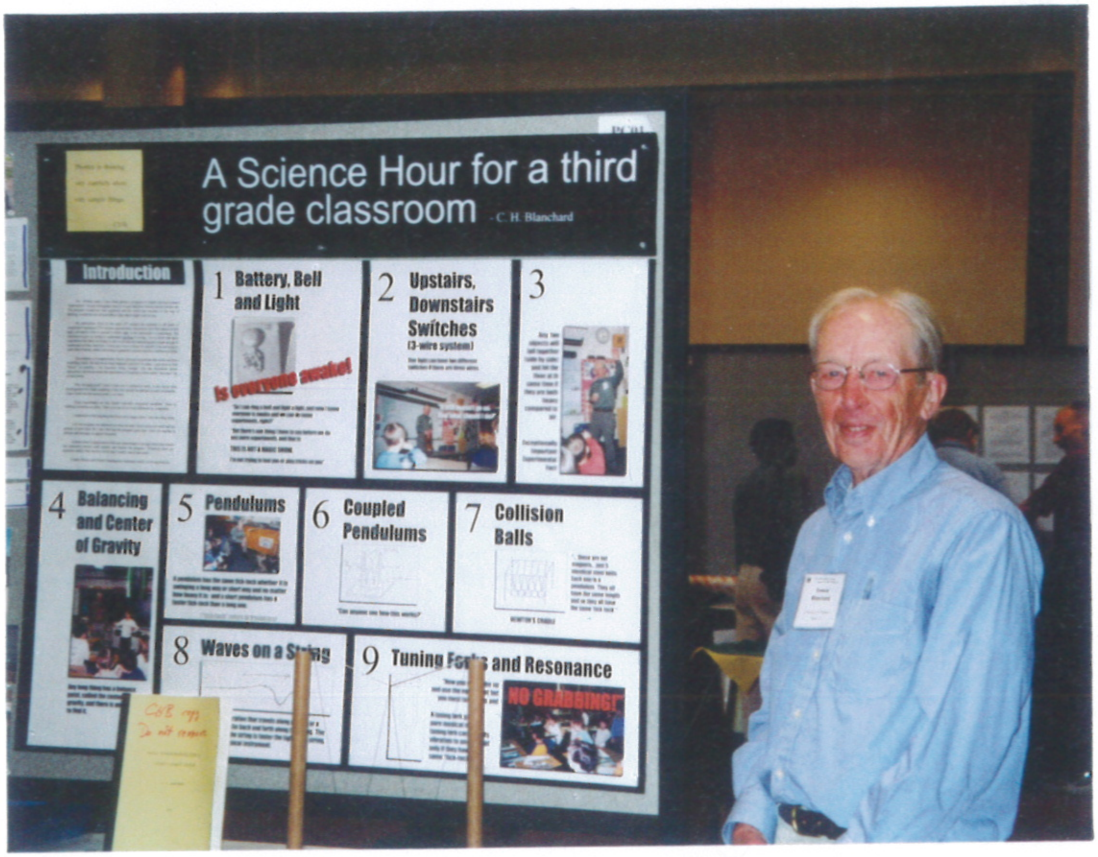
NINE EXPERIMENTS FOR A THIRD-GRADE HOUR

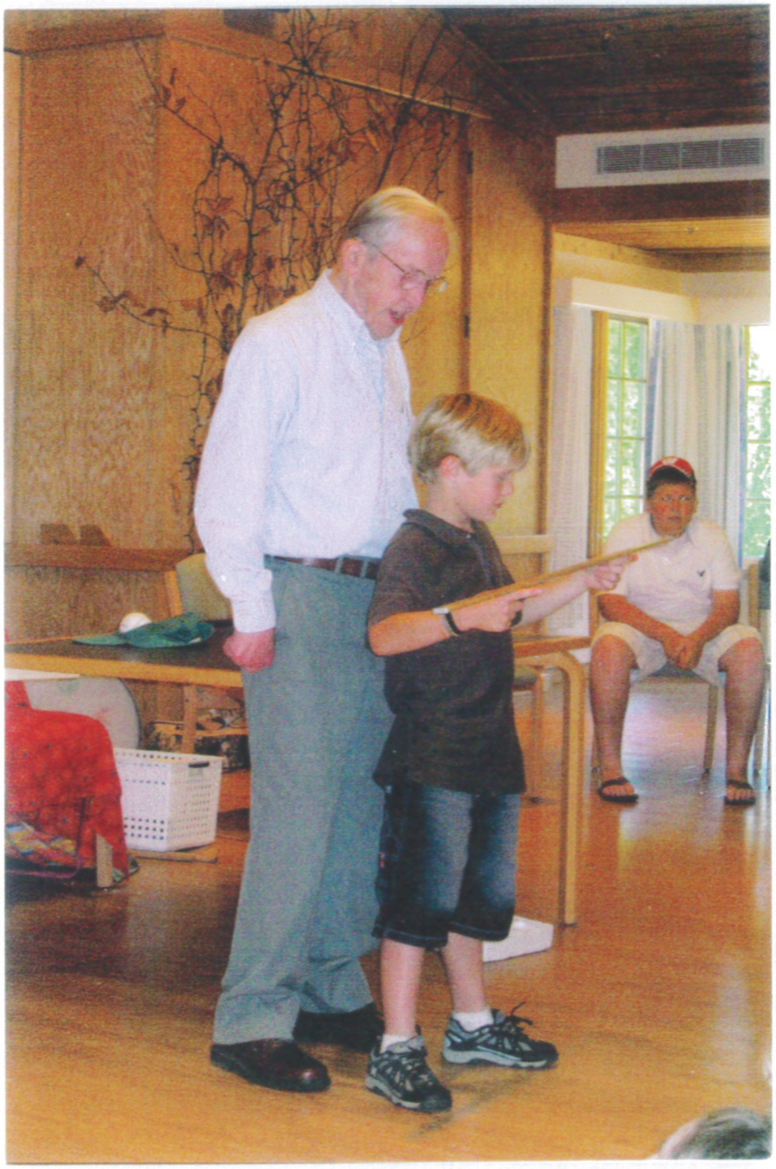


C. H. BLANCHARD

2003
Memorial Edition 2009

NINE EXPERIMENTS FOR A THIRD-GRADE HOUR

Converse H. Blanchard
Professor Emeritus of Physics
University of Wisconsin-Madison



CHB's "Last Science Class" at Bjorklunden (Door County, WI)
Grandparents/Grandchildren/Family Week, July 8, 2009

The assistance of June Weisberger Blanchard is gratefully acknowledged

INTRODUCTION

For several years I have been giving a program of simple physical-science "experiments" to any third-grade class in or near Madison whose teacher invites me. The program comprises nine segments and the whole has become, to my way of thinking, a coherent set of experiences that others might want to use.

My motivation: Kids in the early 21st century are exposed to all kinds of complicated equipment (TV, modern automobiles, electronics, etc.) that appear at first sight, and maybe even at second or third sight, to be impossible to understand. The temptation to give up trying to understand <u>anything</u> is strong. I try to show with these experiments that there are things in this world that are interesting and simple enough to understand and that, therefore, it does pay to try to think for oneself. I am not trying to make little scientists, rather I am trying to generate curiosity and the confidence to think.

The emphasis is on experiments, that is, physical equipment that works and does something visible. We talk about what happened and how it works. I introduce as little "theory" as possible. I do, however, bring "energy" into the discussion where appropriate; and we do notice the importance of frequency (here called "tick-tock") at several points.

Why the <u>third</u> grade? I tried it there and it seemed to work. It also works with fourth graders but I think something of this kind should be enjoyed as early as possible. I have found that the second grade is too early.

These experiments use only simple materials commonly available. There is nothing mysterious or glitzy. There is no use of, or even reference to, computers.

I emphasize at the beginning that this is not a magic show: I am not doing tricks.

I do this program one classroom at a time because I find it does not work well for groups of more than 30. I also find that the program goes best when the teacher is present and manages to appear interested.

In these notes I explain each of the nine experiments in enough detail that almost any interested person could prepare and present the program. Wherever there are quotation marks, they enclose words that I usually use at that point.

Certain themes and deeper meanings are explained briefly in the appendices.

CONTENTS

* Equipment needs to be made or assembled

** Equipment has to be bought

SAMPLE LETTER TO THIRD GRADE TEACHERS

To: ELEMENTARY SCHOOL THIRD GRADE TEACHERS
From: C. H. Blanchard
Emeritus Professor of Physics, UW - Madison

- I am available to present a program of about an hour

SIMPLE PHYSICAL SCIENCE DEMONSTRATIONS

for Grade Three (or possibly Grade Four).

- The emphasis is on simplicity, with some hands-on.

- I am trying to generate curiosity and the courage to think.

- Free of charge.

- **One classroom at a time: it does not work for more than 30 students.**
  May be able to give two classes in one day at the same school.

  Mornings 9 AM or later: Monday through Thursday
  Afternoons: Tuesday through Thursday

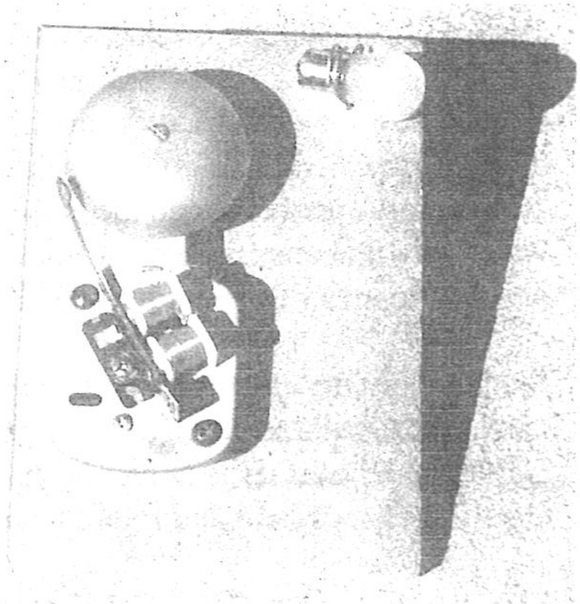
- By appointment with the classroom teacher. Please call at home phone 238-7337 or email <chblanch@wisc.edu>. Evening calls are OK, in fact best. There is an answering machine. (If the answering machine does not respond, then we are not at home and please call again in a few days.)

- This program has been given hundreds of times in public schools in or near Madison in the last decade.

- It's basically the same program again this year and so I shouldn't be invited if the teacher is sick of it.

- A Part-Two demonstration program may be available later in the year, in case you liked the first one.

EXPERIMENT #1: BATTERY, BELL, AND LIGHT



Equipment (all from a hardware store)

- Large 6-volt battery (with spring-like rather than screw-like terminals)
- Two 20-inch (more or less) covered wires, each with alligator clips at each end
- Old-fashioned 6-volt electric doorbell
- 6-volt large flashlight bulb
- piece of wood approximately 12" x 5" x 1"

The Idea of this Experiment:

Electric current ("electricity") flowing around a complete electric circuit, taking energy from a battery and delivering it to a bell which makes a sound wave (which carries energy out into the room) or to a light bulb which emits energy in the form of light.

Procedure:

Don't worry. There's nothing dangerous here (unless you drop the battery on your foot.)

Attach the bell, with its cover off so that its works are visible, and attach the light bulb to the piece of wood any old way. See photograph.

Start by asking "Is everyone awake?" The answer is usually not very responsive. Ring the bell by passing electricity from the battery through it. The students are mildly startled. "Is everyone awake now?" The answer is usually "Yeah!"

Explain how "the electricity" comes out of the positive (+) terminal of the battery and that the same current is going through the bell and back into the negative terminal (–) "to get more energy to keep the bell ringing." (In these simple circuits it doesn't matter which way the electric current goes around and either wire from the battery can be attached to either terminal of the bell, or of the light.)

Explain how the electricity going around and around the copper coils inside the bell makes those coils act like a magnet, making the bell-clapper move back and forth "much faster than I can do it with my finger." You may want to remark that whenever electricity goes round and round it makes a magnetic field down through its middle.

Pass electric current through the light bulb (in at the middle of the bottom and out at the side of the base).

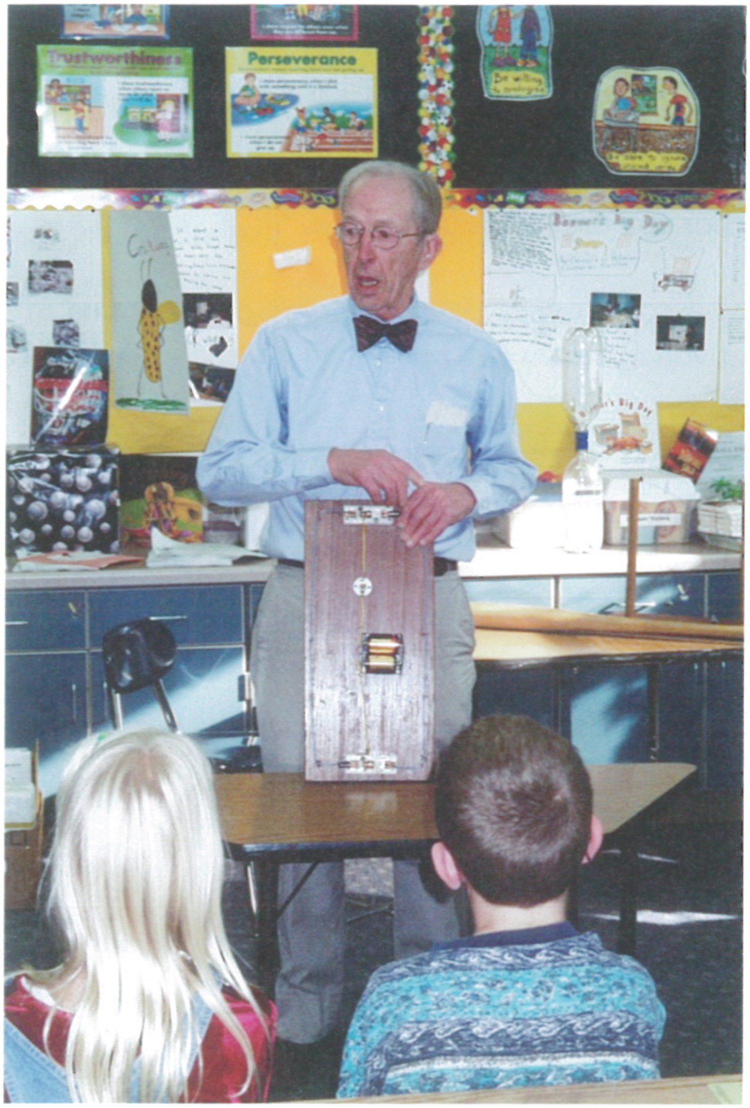
Explain that the electricity going through a wire, called the filament, inside the bulb heats that wire so much that it glows "and that's the light that comes out."

Transition from Experiment #1 to Experiment #2.

"So I can ring a bell and light a light, and now I know everyone is awake and we can do some experiments, right?" The response is usually enthusiastic.

(Now, putting away the bell-battery-light:)
"But there's one thing I have to say before we do any more experiments, and that is:
THIS IS NOT A MAGIC SHOW.
I'm not trying to fool you or play tricks on you."

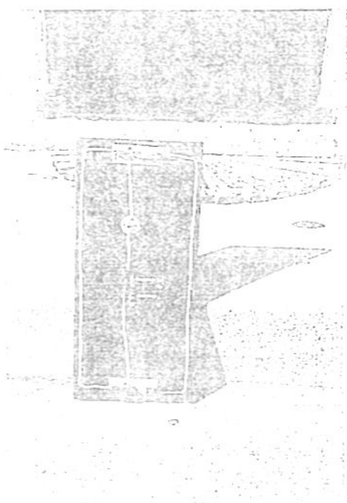
"I want to show you a few experiments, and you can do some of these experiments yourself; so I want you to watch and see which ones you could do at home."

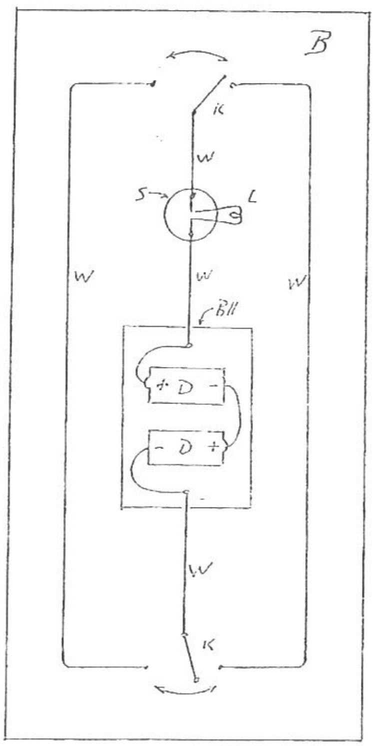

Trustworthiness
Perseverance

EXPERIMENT #2: UPSTAIRS-DOWNSTAIRS SWITCHES (3-wire system)

Equipment:

The equipment has to be made. It is not difficult. See diagram and photograph. The whole is mounted on one side of a <u>piece</u> of wood. Mine is 20" x 9" x 1," but there's nothing special about these dimensions. The following references are to the diagram:





B = wooden board
W = wire, plastic covered, stapled to the board
K = knife switch (2) (single-pole, double-throw) Edmund Scientific 38806
BH =battery holder (Radio Shack)
D = batteries (D cells)
S = bulb socket (hardware store)
L = flashlight bulb

The Idea of this Experiment:

One light can have two different switches if there are three wires.

Procedure:

"OK, we started with electricity so let's continue with electricity for a few more minutes. Does anyone know a place where there's a light over a stairway and a switch downstairs that can turn it off and on (some hands go up) and <u>another</u> switch at the top that can make the <u>same</u> light go off and on?" (Lots of hands go up). (A few students have no upstairs so a reference to a hallway can help.)

"Have you ever wondered how it works? I hope so. I have something here that works just the same way."

With both switches in the neutral position, identify all items, and explain that if the electricity were flowing through the batteries, then it would also be flowing through the light and the light would be on. "But the light is <u>not</u> on, and that is because the electricity has no way to go from the battery through the light and then continue around, back through the battery again."

Close the top switch (one way or the other). "It still doesn't go on. What should I do now?" Other switch! "Right. Which way?" Now it goes on.

Now flip one switch: off, and then the other: back on!

Explain that the board is the stairway, the bulb is the light, the lower switch is the downstairs switch, and the upper switch is the upstairs switch. Someone starting up to bed will turn the light on downstairs (with the lower switch). When safely up the stairs, that person then turns the light off (with the upper switch). A second person will do the same (turning the light on by the bottom switch and turning the light off by the top switch). Someone upstairs wants a midnight snack from the kitchen downstairs: that person switches the light on at the top, goes to get a snack, comes back up, and turns the light off using the upstairs (top) switch.

Electricians call this switch arrangement a "3-wire system." "<u>System</u> just means something that works. This thing works so I call it a system." It's called a 3-wire system because it has three wires.

> Whenever the light is off, if you flip either one of the switches the light goes on. Whenever the lights is on, if you flip either switch the light goes off.

EXPERIMENT #3: FALLING OBJECTS

"Now I want to show you a couple of experiments about gravity. This first experiment is an important one, and you will hear about it again as you go through school studying science. It is a very simple experiment that anyone can do."

Equipment:

Two glass marbles, the same except they should have a different number of colors, and the baseballs, one a real leather-covered and the other a rubber-covered imitation baseball of the same size, shape, and weight.

The Idea of This Experiment:

Any two objects will fall together (side by side) and hit the floor at the same time if they are both heavy compared to air.

Procedure:

The equipment for this experiment is simple. Start with the two glass marbles. "These marbles are made of the same stuff (glass), they have the same shape (round), and the same size (as you can see); and so they have the same weight, right?" (Most students will give tentative assent but some will object that one has more colors than the other.)

"Well let's see. I'm going to hold these marbles up at the same height and drop them at the same time, and see which one hits the floor first. What do you think? Who thinks the (green) one? Who thinks the (blue) one? Well, let's try it." Of course they hit the floor at the same time. Show different times with different heights.

"The color doesn't matter as long as they have the same weight, right?" The students now accept this with ease.

Now do the same experiment with the two baseballs. Ask "Which one will hit the floor first?" Drop them. Of course, they hit the floor at the same time; and by now all agree that this is reasonable.

"OK, now we are ready for the *real* experiment." Hold up one marble and one baseball.

This produces a heated and extended discussion. "Who thinks the marble will hit the floor first? Who thinks the ball? Who doesn't know? (It is sad that many of the girls are happy to give up at this point.) Who thinks they will hit the floor at the same time?" Often no one thinks "same," but occasionally someone remembers seeing this on TV.

"Well, this is a little different. The marble and the ball have different sizes, and I want this to be a fair race, that is, I want them to fall through the same distance. They are going to land on their bottoms, so I'll hold their bottoms at the same height. Then they will fall through the same distance and it's a fair race." Surprisingly, the students seem to accept this rather subtle point with ease.

Drop the marble and the ball. They hit the floor at the same time. Repeat until all agree that the times are the same. (This often requires several repetitions.)

"That's something new, isn't it? It doesn't matter how big they are, as long as they are both heavy compared with air." (More precisely, heavy compared with the air that would be there if they weren't, that is, much denser than air.) "Gravity treats all objects the same, provided they are all heavy compared with air. It wouldn't work if one were a feather, would it? Because a feather isn't heavy compared with air."

You can also let a large fluffy ball of cotton fall slowly, and then "squeeze all the air out of it" and bind it with a rubber band and then it will fall side-by-side with one of the balls.

"I don't want you to take my word for it. This afternoon, please go out in your backyard and find a big rock and a little pebble, and you will see that if you hold them bottom to bottom and you let go at the same time they will hit the ground at the same time."

"Now I'm going to tell you the amazing part. Actually gravity pulls the heavier ball down harder: it has more weight; BUT the heavier ball has more of what we call "INERTIA" which means it is harder to speed up. The lighter marble isn't pulled down as hard but it is easier to speed up. The amazing thing is that all this comes out even and they fall side-by-side."

This is an exceptionally important experimental fact.

EXPERIMENT #4: BALANCING AND CENTER OF GRAVITY

Equipment:

Meter stick and full-size, wooden, no-tape baseball bat.

The Idea of this Experiment:

Any long thing has a balance point, called the center of gravity, and there is an easy way to find it.

Procedure:

"Here's another gravity experiment that I think you will like. We do it with this."
Hold up a meter stick (with inches on the back).
"What is this thing?" A ruler. "Yes, but what kind?" A yard stick. "Yes it looks like a yardstick, but it's more than 36 inches, so what is it?"
Somebody says "a meter stick," and we talk about the metric system: meters, centimeters, and kilometers. ("Kilo means 1000.")
"O.K. that was just for fun but now here is the experiment."

Ostentatiously rub both sides of the meter stick on your slacks and rub both index fingers ("so they're equally dry"). Place the meter stick on your index fingers, each near an end (but not necessarily equally far from the center). Push your fingers together slowly and steadily. The audience is breathless! Your fingers will take turns slipping along the stick and will come together at the center of the stick, the stick will stay balanced. And it becomes obvious that the "balance point" of the stick is at its middle.
"Why is the balance point in the middle?"

Have a kid do it. Then have another "do it faster."

"Now, is it going to work with this?"
Hold up the baseball bat. Most reply no, a few say maybe. Again your fingers come together and the bat stays balanced, but, of course, now not at the middle but rather at the center of gravity. "Everyone say it 'Center of Gravity.' It is the center at which I can balance the whole of gravity."
(Don't say "equal weights": that's only true for a symmetrical object.)

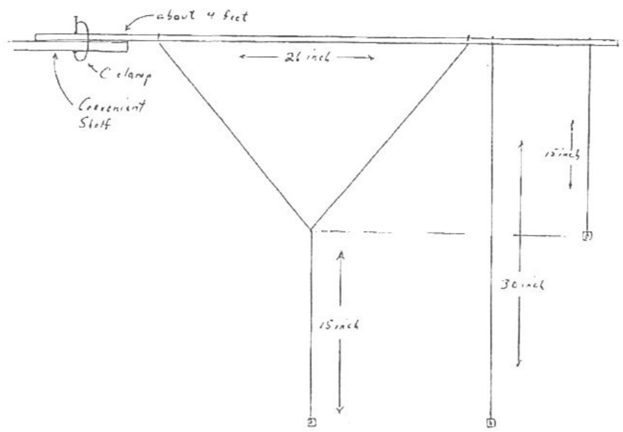
Whatever long object (golf club, hockey stick, broom, mop, rake), your fingers will come together under the **center of gravity**. This is a good experiment to show your family at home tonight with a broom.

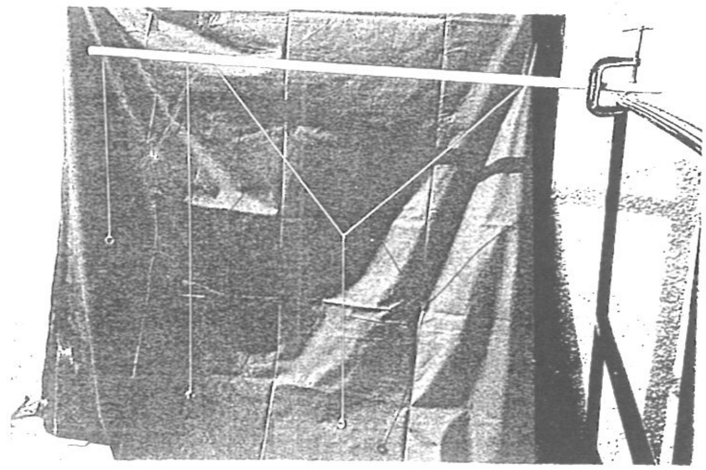
You may want to explain why it works, with the meter stick. The more distant finger is always bearing the lesser weight and will therefore be the one that slips first, until the other becomes the more distant.

CHB and grandson, Ben Blanchard, in Ben's 4 year old nursery school classroom in Madison, WI, in year 2001

EXPERIMENT #5 PENDULUMS

Equipment (easily made -see diagram and photo):





The Idea of the Experiment:

A pendulum has the same tick-tock whether it is swinging a long way or short way and no matter how heavy it is; and a short pendulum has a faster tick-tock than a long one.

Procedure:

I have the kids come and sit on the floor, clustered around the pendulum stick. Demonstrating with the long pendulum, say "A pendulum is just a weight at the end of a string. It swings back and forth through the center (the lowest point) repeating the same motion over and over, always taking the same time to do it."

Now swing it along a different line. "It's the same pendulum and has the same tick-tock." (This introduces "tick-tock.")

Swing it around in an oval and say "It can also swing in an oval, but that is a rather complicated motion and it's not what we usually mean by a pendulum."

"The most interesting thing about a pendulum is what I'll show you first, but you're going to have to say the tick-tocks along with me."

Pull the long pendulum way out (say 25°), let go, and have everyone say "tick-tock, tick-tock..." until a regular rhythm is established. Now, instead, pull it out just a little bit (say 5°) and hear the same rhythm established. Push it a little more and hear that the tick-tock does not change.

"It's the same tick-tock whether it's swinging a lot or a little. How can that be?" Lots of discussion until someone says that when you pull it way out, it has a long way to go, but it goes faster. (A pendulum is "isochronous," meaning that it has the same tick-tock so matter how far out it is swinging. The textbooks arcanely report this as: the frequency is independent of the amplitude.)

"That's probably the most interesting thing about a pendulum, but here's another thing." Swing the long pendulum and the short one side-by-side, perpendicular to the plane of the diagram, and learn that the shorter pendulum has the faster tick-tock. (Don't say "goes faster.") You can make the short pendulum even shorter by wrapping its string around the stick and hear faster and faster tick-tocks. (The kids seem to like this.)

Swing the long pendulum and the Y pendulum side-by-side perpendicular to the plane of the diagram and learn that they have the same length and the same tick-tock. Now swing the short pendulum and the bottom of the Y in the plane of the diagram and again find the same tick-tock for the same length.

Now put some extra weight (hang another nut) on the long pendulum and see that it still has the same tick-tock as the Y pendulum. "This is just like the marbles and balls dropping. The heavy ball and marble took the same time to hit the floor; and here, if we have a heavy pendulum and a light pendulum, they take the same time to swing back and forth. (This is an important connection. Once in a long while a bright kid will say this before you do. This is about as rewarding as student responses ever get.)

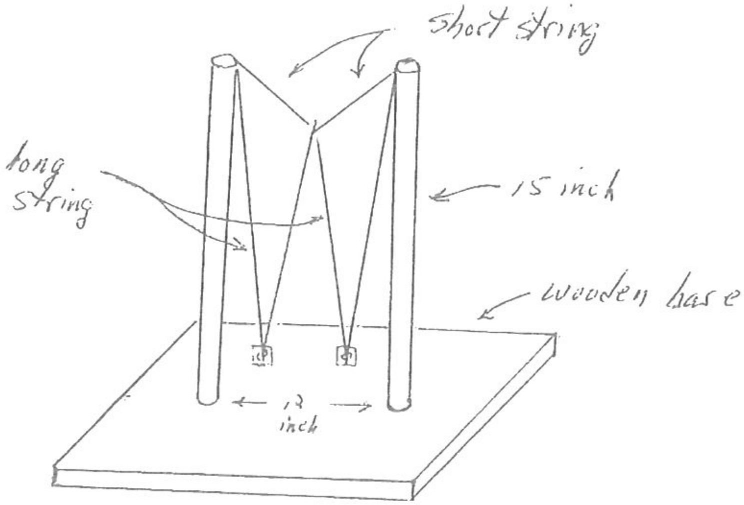
Finally, set the Y swinging both ways at the same time. Observe chaotic motion: it never repeats "It takes different times to swing back and forth than to swing side-by-side and so the two motions cannot fall in step with one another to form a repeating pattern."

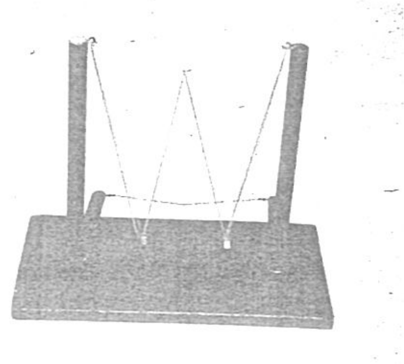
A pendulum has the same tick-tock if it has the same length, no matter how far it is swinging and no matter how heavy it is. (Of course, the weight on the pendulum must be much heavier than the string but not so heavy as to break the string.)

EXPERIMENT #6: COUPLED PENDULUMS

Equipment (is easily made):

Two dowels glued into holes in a wooden base. A short string between their tops and a long string also between the tops, just draped over the short string, and with two weights (heavy steel nuts).





The Idea of the Experiment:

Two pendulums that can wiggle each other can pass the whole motion back and forth to each other if they are the same length (have the same tick-tock).

Procedure:

All the motions here are small swings perpendicular to the plane of the dowels.
"I'd like to show you another pendulum experiment."
(a) There are two pendulums; hold one and swing the other.
(b) Show that when they are not equally long then they have different tick-tocks.
(c) If they are adjusted to be equally long then they have the same tick-tock and they can swing together (stay in step: side-by-side).
(d) Also, if they are equally long they can "march": swing oppositely, one in when the other out. (The tick-tock of this marching motion is a little faster than that of the side-by-side motion!)

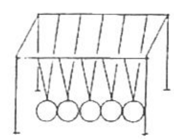
"Those are the two simple motions of this system of two pendulums." (They are the so-called "normal modes.")

"But their interesting motion is what I'll show you now."
(e) Still adjusted (quite carefully) to equal lengths, start one of them swinging. The one that's started begins to pull the other into motion. The other goes faster and faster while the first slows down, and stops when all the motion is on the other. Then the other, in turn, sends the motion back to the first.

"Can anyone see how this works?" On the same moving string.

"All the motion is passed from one to the other on the same moving support string. This can only happen is they are just alike, so that whatever motion one can have, the other can have the same motion."
Show that if they are not the same length then there is incomplete transfer of motion (and, of course, energy) from one to the other.

EXPERIMENT #7: COLLISION BALLS (Newton's Cradle)



Equipment Notes:

Note 1: This equipment has to be bought. Mine is from Ann Arbor Scientific, P.O. Box 2750, ANN Arbor, MI 48106, Catalog # P1-6001. Should cost less than $30.

Note 2: This is the experiment the students like best. Most have seen it before and they get very excited when they see it, so KEEP IT OUT OF SIGHT UNTIL NOW.

Note 3: The balls are meant to move only along the line of the balls at rest. Other motions tend to break the strings.

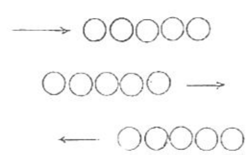
Note 4: Keep the motions down below 25°. If you pull a ball way up and out and let go, they strings will often get awkwardly tangled.

The Idea of this Experiment:

The motions are simple enough to be interesting because the balls are all alike and the collisions are all alike.

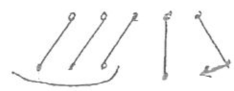
Procedure:

"The first thing I must say is that these are not magnets. There are no magnets here: just five identical steel balls."

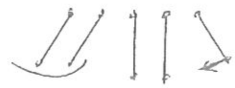


(1) "Each one is a pendulum. They all have the same length, and so they all have the same tick-tock, and they all swing back and forth together."
Push gently once:
"They're not sticking together and they're not bumping into each other. They're just quietly swinging side-by-side because they all have the same length and the same tick-tock."

(2) Hold three balls up out of action with one hand, and, with the other hand, let the other-end ball collide with the remaining ball. "Now you see the simplest kind of collision there is: all the motion is passed from one ball to the other. This can happen only if the balls are just alike, so whatever motion one can have the other ball can have the same motion. One ball in and one ball out."

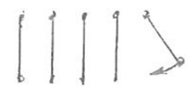


(3) Hold two balls up out of action and with the other hand let the end-ball collide with the two remaining balls. Two collisions: one ball in and one ball out. Each ball stops as it hits the next one, but the last ball can keep going.

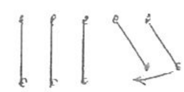


(4) Hold one ball up out of action and with the other hand let the end-ball collide with the remaining balls. Three collisions: one ball in and one ball out.

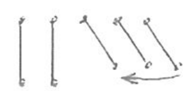
(5) Four collisions:



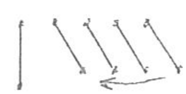
(6) Two balls in and two balls out.



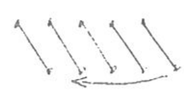
(7) Three balls is and three balls out.



This is the point at which the kids see that there's something really interesting here.



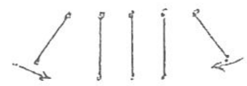
(8) Four balls in and four balls out.



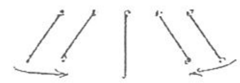
(9) Five balls in and five balls out. (Yes, it's OK.)

(10) One and one.

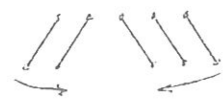
(11) Two and two.



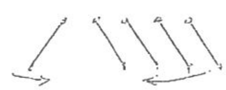
(12) Three and two. 3 and 2, 2 and 3, 3 and 2 . . .



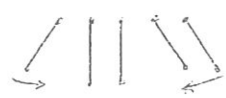
(13) One and four. 1 and 4, 4 and 1, 1 and 4 . . .

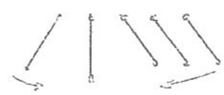


(14) Do one and two 1-2, 2-1, 1-2..... and then say "What's the only one that I haven't done yet? The logical kid in the class will say, immediately, three and one. (This is a mini-IQ test.)

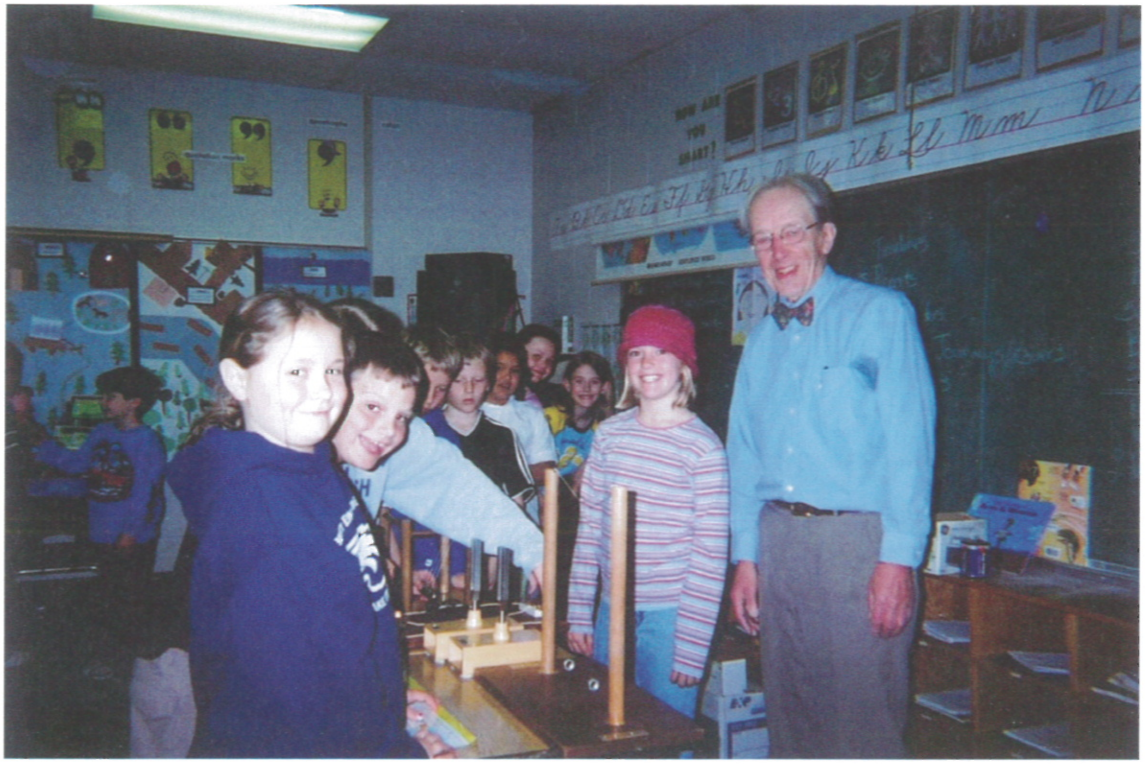


(15) Pull all the balls out at one end and let them go one-at-a-time (letting them slip between your hands.). "What does it sound like?" (It's more regular than firecrackers, rain, popping corn, hail.) A horse running? Yes, because all the motions here are repeated over and over with the same tick-tock.





This equipment is often called Newton's Cradle, because it looks like a cradle and Newton is the person who explained how things like this work.



CHB and granddaughter, Carolyn Patt, with her third grade classmates in Eau Claire, WI, in school year 2003-2004.

EXPERIMENT #8: WAVES ON A STRING

Equipment:

A long (50 feet or so) piece of well-used (limp not stiff) cotton clothesline.

The Idea of this Experiment:

A wave is a vibration that travels along a string (or rope). It can echo back and forth along the string. Two waves can pass through each other. The tick-tock of the string is faster the tighter the string, just as in a musical instrument.

Procedure:

Tie one end of clothesline to the top hinge of the door of the room and then stretch the rope from there to you in the farthest corner of the room.

1. Swing your end around slowly and make a jump rope pattern. Swing it faster and make a double-loop pattern. Swing it faster yet and get three loops. Treat this as just fun (but you are showing how the wavelength of a wave gets shorter when its frequency gets higher).

2. Hold the rope moderately tight and tap it sharply with your finger. A ripple travels along the rope, and bounces back from the other end. "What is that thing?" A vibration. "Right. It goes down to the other end and it can't shake the wall so it can't go into the wall; and that energy has to go somewhere so it bounces back. "It's a vibration that travels along. Does anyone know a name for a vibration that travels?" (Waving hand) A wave. "Right." What do you call it when a sound wave bounces back?" An echo. "Right."

3. Have a kid reach up and hold the rope firmly at some point near the middle. Now the wave bounces between her and you. "She's so strong that the wave can't move her hand and so the wave bounces between her and me." Then have the kid make an O around the rope (with thumb and index finger). Now some of the wave gets through and

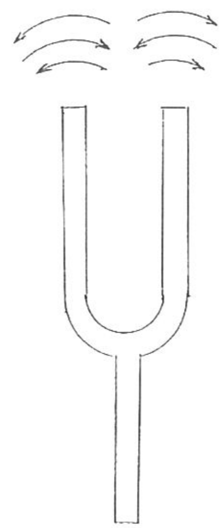
some bounces back (from the O). Excuse the kid with thanks.

4. Hit the string twice in succession so there are two waves bouncing back and forth. Tell the kids that it is difficult to see but that you hope they can see that these two waves are moving back and forth "each as if the other were not there. In other words, these waves go right through each other. This is something special about waves: they can go through each other. People can't go through each other. Automobiles can't go through each other. But waves can go right through each other. That's why there can be two people talking (making sound waves) in the same room at the same time. Those sound waves can go right through each other" (also radio waves and flashlight beams).

5. Now hold the rope rather loosely and count "tick-tock" as the wave bounces back and forth. The string has a slow tick-tock if it is very loose. Pull the rope tighter and learn that now it has a faster tick-tock. Pull the rope very tight and then it has a very fast tick-tock.
"Just as in a musical instrument (guitar, violin, piano), the tighter the string the faster the tick-tock and the higher the musical note.

EXPERIMENT #9: TUNING FORKS AND RESONANCE

Equipment:



For this experiment you need a matched-pair of tuning forks with resonator boxes, additional weights, and rubber hammer. This equipment has to be bought as a package, and is the most expensive ingredient of this program. Furthermore, the sets advertised in most catalogues are just <u>not good enough</u>. Try before you buy. I have a pretty-good pair from American 3B Scientific, 2189 Flintstone Dr., Tucker, GA 30084. (1-888-326-6335) Expect to pay upwards of $70.

The Idea of this Experiment:

A tuning fork gives a pure musical note. A tuning fork can pass its vibration to another but only if they have the same tick-tock (if they are the same musical note).

Procedure:

1. Holding one fork by its stem, tap it far up on its side with the rubber hammer. It makes an audible music note which is easily stopped by grasping the top of the fork. "The fork vibrates, making the air next to it vibrate, and these vibrations travel all through the room, giving the sound wave that you hear. It makes a pure musical note so it can be used to tune things (piano) and it sort of looks like a fork, and so it is called a tuning fork."

2. Touch the stem to the hard table. Note that the sound is much louder because the whole table vibrates, and acts like a "sounding board." The vibration dies out much faster (sooner) when it's having to shake the whole table.

3. Insert a fork into the holder on top of one of the resonator boxes. Loud pure musical note (mine is 440 Hz: A above middle C). Then put your hand over the mouth of the box which stops most of the sound which resumes when you remove your hand.

Explain that the vibration of the fork makes the top of the box vibrate and that makes the air inside the box vibrate and those vibrations travel out of the box as a sound wave which goes everywhere in the room.

4. Put a penny in the box and do it again: Audible rattle as the penny bounces up and down because the box is vibrating underneath it.

5. Show that the vibration is stopped by grasping the fork with your hand.

6. Now put the other box-with-fork on the table. Tap one fork and the other repeatedly and rapidly to establish that they are the same note. Same note: same pitch: same tick-tock.

7. "Now we do the Main Experiment." Tap one fork and, in a second or so, stop it with your hand and now hear that the other is now vibrating! "A sound wave comes out of the hit one, and goes all over, but a little bit of it goes into the other box. The other fork has the same tick-tock as the struck one and so it can fall in step with the wave vibration and starts vibrating. This is an example of "resonance" or "sympathetic vibration": two objects with the same tick-tock will fall in step with each other. It works from either box to the other, of course.

8. Put an extra weight on one fork near or at the top of one of its tines and hear that the two notes are different. Hit and stop one and then hit and stop the other. The heavier fork vibrates more slowly and gives a lower musical note.

9. Do the Main Experiment again. Now the unhit fork remains mute. Different tick-tock: can't fall in step and doesn't start vibrating. Doesn't work the other way, either.

10. Now put an equal weight at the same place on the other fork as well. Now it works again because they have the same musical note, and they fall in step with each other.

11. Finally, leave a weight on one of the forks and take the weight off the other, and then hit them both. Now hear musical beats as the two different tick-tocks fall in and out of step with each other, as time goes on.

EXPERIMENT #10: HANDS ON

If time permits, and it's OK with the teacher, say "You may come up now and use the equipment, but remember: equipment works best when it's used gently."

"You must take turns and NO GRABBING."

SCIENCE FOR THIRD GRADERS

In my retirement I wanted to do something about the abysmal condition of scientific literacy that surrounds us. For various reasons I decided to work with third graders, and their teachers. I have developed a program of elementary physical-science "experiments" (actually standard demonstrations). I go with a large box of equipment and do these experiments for an hour. I do one classroom at a time, so that I have pretty good contact with individual students. I do not lecture at all. We do experiments and talk about how they work. It is great fun. Third graders are still very nice people. They respond well to experiments carefully presented.

We do simple electric circuits, falling objects, pendulums, collisions, waves on a string, and resonance with tuning forks. We talk a little about energy and a lot about frequency (which we call "tick-tock," having introduced it with pendulums). I think the sequence of experiments has some coherence.

The teacher sometimes expresses surprise that the students stayed interested for a whole hour. Often the teacher appears to be one of the more interested students in the class, and this makes it even more enjoyable for me. There is a great deal of audience participation and it is easy to spot the alert ones. Sometimes I have the pleasure of seeing a student sort of catch fire. I am not trying to make little scientists, rather I am trying to generate curiosity and the courage to think.

I do about one hundred classrooms a year, in and around Madison. I have been doing it for a decade and so some of "my" students are now entering college. I make arrangements directly with the classroom teachers. They are most receptive (but usually after I assure them that there is no charge).

12/11/2003

A BRIEF SUMMARY:

1. **Battery, bell, and light bulb** (with filament).
   Electricity going around in a circuit. Electricity delivering energy from the battery to the bell and to the light.

2. **Upstairs-downstairs switches.**
   Three-wire system.

3. **Dropping marbles and balls.**
   Gravity treats them the same.
   (The one with more weight also has more **inertia**.)

4. **Balancing meter stick and bat.** Center of gravity.

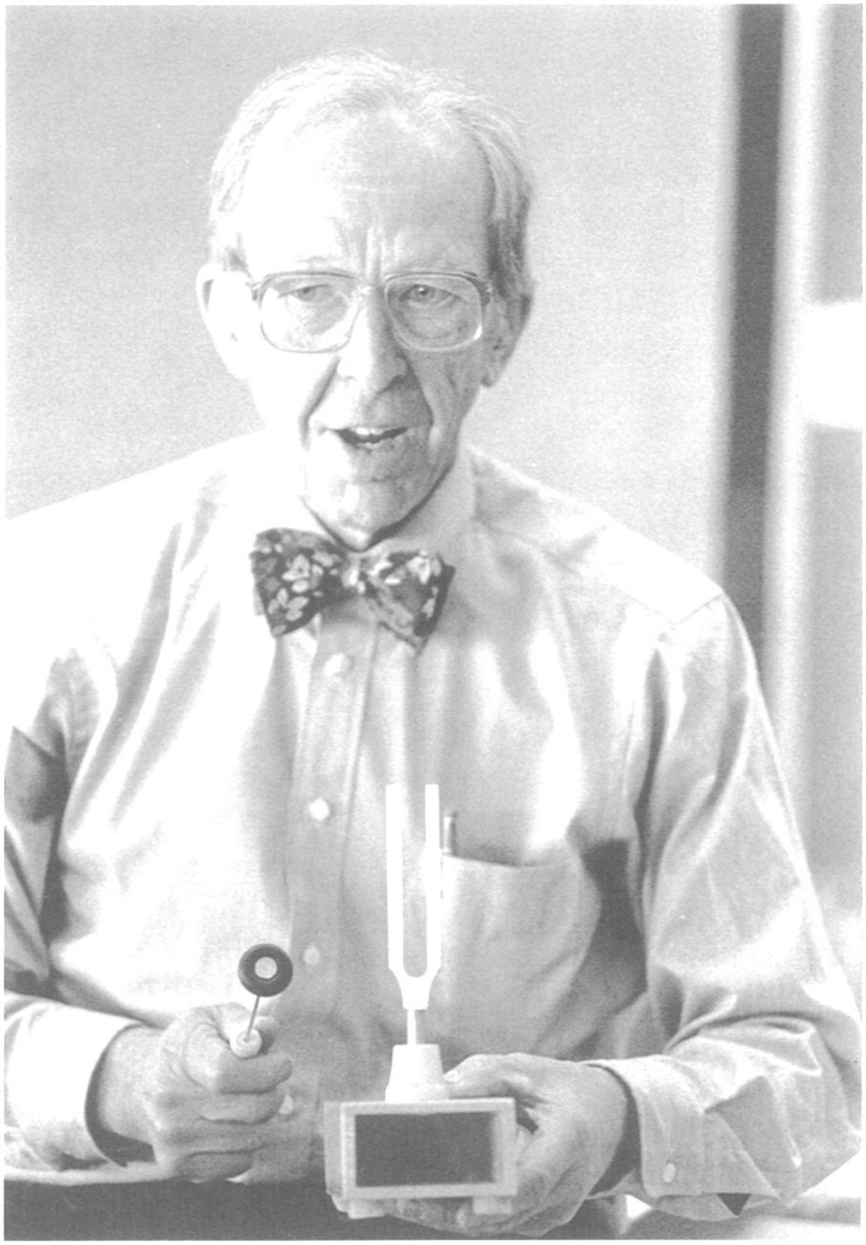
5. **Pendulums.** Same length gives the same "tick-tock" (frequency) no matter how heavy they are and no matter how far they swing.

6. **Two pendulums on the same string**
   (coupled pendulums).
   The <u>whole</u> motion is passed from one to the other <u>only</u> if they have the same length (same tick-tock).

7. **Collision balls** (Newton's cradle).

8. **Vibration traveling along a rope.**
   Wave. Echo.
   Tighter string has faster tick-tock and higher musical pitch, as in a musical instrument.

9. **Tuning forks.**
   Vibration makes a sound wave throughout the whole room. Vibration from one is picked up by the other <u>only</u> if they are the same musical note: only if they have the same tick-tock. If they do have the same tick-tock then they can fall in step with one another and they are said to be "in resonance."

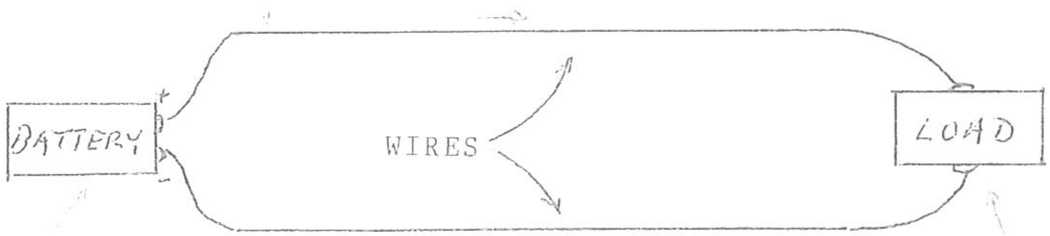


UNDERLYING THEMES AND DEEPER MEANINGS

1. ***ENERGY*** is a central concept and an important quantity in all physical sciences. The energy of an object (or body or "system" of any kind) is the amount of "work" that can be extracted from it (directly or indirectly as with the use of some kind of machine). The simplest example of "work" is the lifting of a weight (more generally: exerting a push or pull through a distance). Energy is important because it is <u>conserved,</u> which means it cannot be created or made to disappear: it can only be changed from one form to another. (This conservation is an amazing and purely empirical, or experimental, fact.) There are many forms of energy: kinetic (energy of motion), gravitational (energy of height), mechanical, electrical, thermal (heat), chemical, nuclear, to name the most prominent.

2. ***ELECTRIC CIRCUIT***

Current of high-energy electricity, carrying energy from the battery to the load.



Energy to the electricity from the battery.

Energy from the electricity to the load.

Current of low-energy electricity, Returning to the battery to get more energy.

The load can be a bell or a light or an electric motor, etc. Each of the two wires is carrying the same amount of electric current.

3. In Experiment #3 (***FALLING BODIES***) we find the "equivalence of the inertial mass of an object and its gravitational mass." A heavier object is pulled down by gravity harder, but its resistence to acceleration (its inertia) is proportionately larger, and so they take the same time to hit the floor. (This is an important feature of Einstein's theory of gravity.) The same thing happens in Experiment #5 where a heavy pendulum and a light pendulum take the same time to go back and forth (because the same forces are involved).

4. ***PERIODIC MOTION*** is motion that is repeated at exactly equal time intervals. ("Periodic" means repeated regularly in time, not just "occasional.") The time interval is called the period. Periodic motion is an important feature of all the Experiments #5 through #9. In Experiment #5 we introduce the "tick-tock." Of course we are talking about the frequency of the motion: the number of times it occurs per second (or per minute, or per hour: you have to say which). A frequency of 1 Hertz (Hz) is a frequency of one full back and forth motion per second. The musical note A-above-middle-C has a frequency of 440 Hz (440 vibrations per second). An FM radio wave has a frequency of 100 million Hz.

Experiments #5, #6, and #7 involve pendulums that have a definite tick-tock (frequency). In Experiment #8 we learn that the frequency of a wave on a string is faster the tighter the string. In Experiment #9 we see the effect of "resonance": that vibrating objects can respond to one another (fall in step with each other) if they have the same frequency.

[It is an amazing mathematical fact that any process of a physical system can be described in terms of the frequencies to which that system can respond. Such analysis is called Fourier (FOO ree ay) Analysis.]

5. In Experiments #6, #7, and #9 we see that energy transfer between two objects is more complete the more nearly alike the objects are.

THE SCIENTIFIC METHOD

In my retirement I do one-hour programs of science "experiments" for third graders, one classroom at a time. The experiments are about simple physical science: falling objects, simple electric circuits, center of gravity, pendulums, resonance with tuning forks, etc. It is great fun. Third graders are wonderful people. They respond well to simple experiments carefully presented.

Of course this program works best when the teacher is present and manages to appear interested. Sometimes it becomes clear that the teacher is learning more than the students, and that makes the class doubly enjoyable for me.

I do sometimes see in the classroom traces of an old-fashioned attempt to give a strict definition of <u>the</u> scientific method, often with a fixed number of definite steps, and often involving the mysterious word "hypothesis," a word the kids have not heard before, and few will ever have the occasion to use. Such attempts can lead the student to think that there is just one way to do science and also that if this procedure is followed success will ensue.

It is important for students to realize that there are many different kinds of activity and circumstances that can generate scientific ideas. Intensive study and experimentation are, of course, often the necessary hard work. Out of quiet reflection, after the hard work, can pop a whole new insight or solution. Luck is sometimes involved but usually has to be accompanied by thoughtful observation. Often a new idea results from trying to understand an experimental result different from any of the possible results expected at the beginning of the work.

I offer a simpler, more flexible, and more appealing definition. I submit that if there is a scientific method it is

Figuring Out How Things Work.

Of course, it must be made clear that we mean <u>all</u> things, not just man-made complexities like automobiles and computers, but also all the things that occur in the natural world. It is figuring out how living bodies and molecules and DNA and galaxies and electromagnetism and waves . . . . . work. I think this definition is accurate and that it has strong appeal to beginning students.

5 December 2003

C. H. Blanchard
Professor Emeritus of Physics
UW-Madison

2021 Van Hise Ave.
Madison, Wisconsin 53726
20 September 2006

To: My Teacher Friends
From: Connie Blanchard

I am sad to report that I shall no longer be visiting schools with my science program.

I have done about 1670 classes (in 13 years) and, at 18 students per class, this is about 30,000 kids. I actually feel pretty good about that.

At my age (83 this month) I really should no longer be driving much. Also I tire much more easily now-a-days.

I shall miss this activity, the kids, and the kind, heroic, and selfless teachers who invited me to do my thing.

My activities will now be mostly centered on the UW campus area (to which I can walk or bus). In particular, I hope to be available to students of all ages and school classes who can visit the UW Physics Museum (now enlarged and refurbished) in Chamberlin Hall on campus. I have not yet worked out the mode of my availability, but I would be glad to discuss possible Museum tours.

Physics is thinking
very carefully about
very simple things.

CHB

1923- 2009