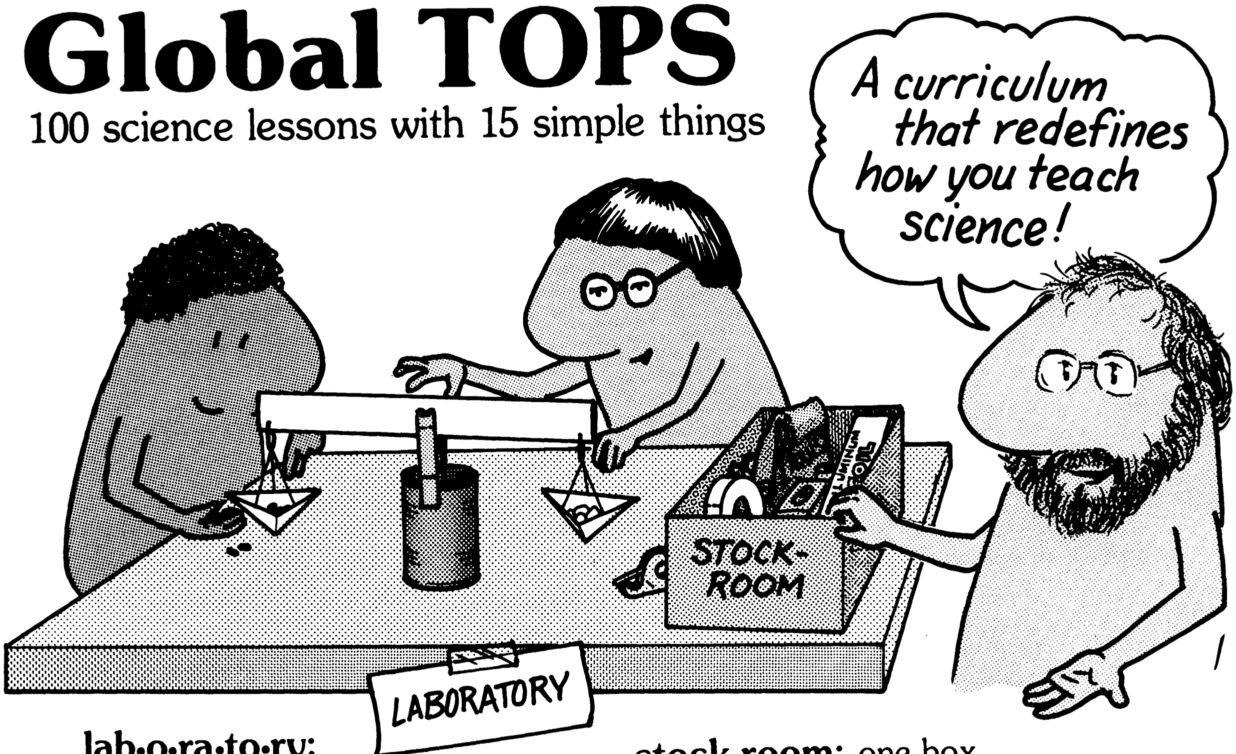
Global TOPS

100 science lessons with 15 simple things



lab•o•ra•to•ry: any room with tables and chairs.

stock•room: one box of inexpensive materials.

TEACHER RESOURCE MANUAL

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CONTENTS

GATHERING MATERIALS

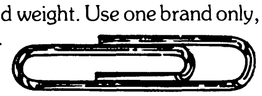
This page lists *everything* you'll need to complete all 100 TOPS activities. To understand which of these materials are specifically used in any given topic A through O, please consult the appropriate sublist in the introduction to each topic.

Materials to Purchase

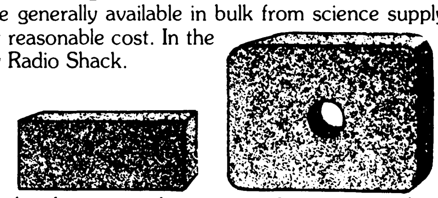
Gather everything in a single afternoon, or add materials as you teach. If you follow an A through O alphabetical sequence, then all items are listed in order of first use. Thread is needed first, for example; dry-cells are not required until activities H; nails are first used in activities M.

Quantities are sufficient to support 30 students working in lab groups of 2. In 1988 US dollars, expect to spend roughly $140.00 if you purchase everything on this list in the recommended quantities. Spend about $75 per year thereafter to resupply consumables. Dry cells and bulbs *alone* account for over half of this total expense. Cutting back on these 2 basics will dramatically lower your overall costs.

- 1 spool — **Thread**.
- 15 pair — **Scissors**.
- 11 boxes — **Paper clips** of uniform size and weight. Use one brand only, medium size, about this large. At 100 paper clips per box, you need 1,100 total.



- 5 rolls — **Masking tape**: 3/4 in x 50 yds or longer (1.9 cm x 46 m).
- 120 — Medium-sized **rubber bands**.
- 8 rolls — **Clear tape**: 1/2 in x 12 1/2 yds or longer (1.3 cm x 11 m).
- 1 box — Steel **straight pins**. Aluminum pins must not be substituted.
- 90 — Wooden spring-action **clothespins**.
- 2 rolls — **Aluminum foil**: 12 in x 25 yds (30 cm x 23 m)
- 60 — Size-D **dry cells** (1.5 volts). Sold most economically in boxes of 36. Paying extra for higher quality is worth your money.
- 40 — Flashlight **bulbs**. Bulbs with collars are better than screw-in kinds. Use a size that is designed for 2 dry cells (3 volts).
- 1 box — Fine grade **steel wool**. Do not substitute soaped pads.
- 70 — Small ceramic **magnets**, with or without a center hole. These are generally available in bulk from science supply outlets at reasonable cost. In the USA, try Radio Shack.



- 1 roll — Plastic-insulated **copper wire**: approx. 24 guage, 200 ft or longer (61m). Diameter is not critical, but the wire should be thin enough to easily bend back and forth. Avoid bell wire with a baked-on enamel finish.
- 30 — Medium-sized **nails** about 2 1/2 in (6.5 cm) long. Size is not critical.

Materials to Recycle

In addition to the 15 basics listed above, review this inventory to determine (a) what additional materials (if any) you need to purchase; (b) what you already have on hand; (c) what recyclables your students can bring from home. Notice that some items are optional, while others are used in only a single experiment. Materials are again listed in order of first use.

Quantities are sufficient to support 30 students working in lab groups of 2.

- 1 — Wall **clock** with second-hand sweep. Your students can substitute wristwatches if they have them.
- 30 — Small **coins** (pennies) of uniform size.
- 15 — Hand **calculators** (optional). Mental long division and multiplication is probably more beneficial.
- 30 — Medium-sized tin **cans**.
- sm pkgs — Local **seeds**. Use pinto beans, popcorn, lentils and long-grained white rice, or equivalent. See "Preparation" in teaching notes D-3 and O-1.
- 15 — **Bottle caps**. Different sizes are OK.
- 15 — **Pen caps**. Different sizes are OK.
- 1 handful — **Scratch paper**. Some sheets should be the same size.
- 1 — A **water** source plus buckets or other large containers for easy distribution.
- 30 — **Small glass jars with lids**, 1 pint (500 ml) or smaller. At least 15 lids must fit tightly.
- 15 — **Large glass jars**, 1 quart (1000 ml) or larger.
- 1pkg — Refined **sugar**. (Used in 1 activity.)
- 1pkg — Refined **salt**. Seal tightly against moisture for easy pouring. (Used in 1 activity.)
- various — Local **insects and animals** to observe.
- 1 ball — **String**. (Optional for 1 activity.)
- various — A **coloring system**: Paints, crayons, or colored pencils. (Used in 1 activity.)
- 1 handful — **Newspaper**.
- 1 bucket — **Soil**. Use local variety or purchase a small bag of potting soil.
- 1 sq yd — **Plastic wrap**. Use plastic bags or a roll of plastic wrap.

School Supplies

Every student is individually responsible to turn in a separate report for each completed activity. As such, each one must have the following basic supplies.

- 1 — A **system to organize and store assignments**. This might be a spiral-bound or loose-leaf notebook, a copy book, or notebook paper stored in a file folder.
- 1 — A **pencil**.
- 1 — An **eraser**.

A TOPS Model For Effective Science Teaching. . .

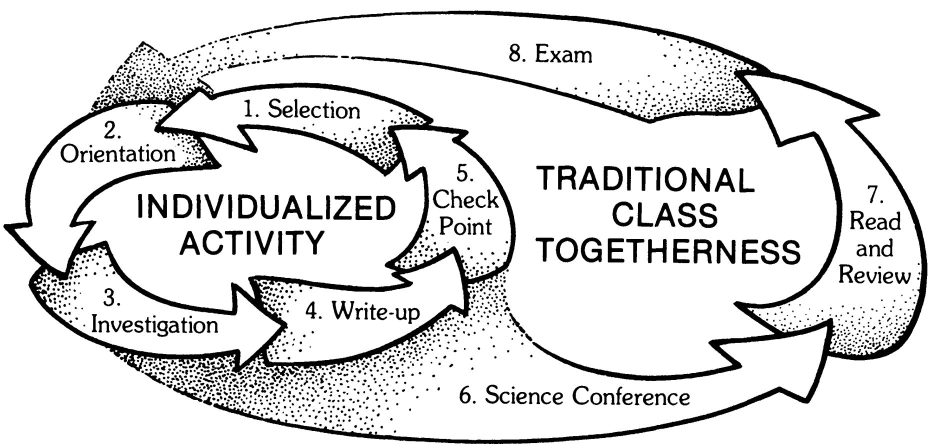
If science were a set of explanations and a collection of facts, you could teach it with blackboard and chalk. You could assign students to read chapters and answer the questions that followed. Good students would take notes, read the text, turn in assignments, then give you all this information back again on a final exam. Science is traditionally taught in this manner. Everbody learns the same body of information at the same time. Class togetherness is preserved.

But science is more than this.

Science is also process — a dynamic interaction of rational inquiry and creative play. Scientists probe, poke, handle, observe, question, think up theories, test ideas, jump to conclusions, make mistakes, revise, synthesize, communicate, disagree and discover. Students can only learn these things if they are also free to think and act like scientists, in a classroom that recognizes and honors individual differences.

Science is *both* a traditional body of knowledge *and* an individualized process of creative inquiry. Science as process cannot ignore tradition. We stand on the shoulders of those who have gone before. If each generation reinvents the wheel, there is no time to discover the stars. Nor can traditional science continue to evolve and redefine itself without process. Science without this cutting edge of new discovery is a static, dead thing.

Here is a teaching model that combines the best of both elements into one integrated whole. It is only a model. Like any scientific theory, it must give way over time to new and better ideas. We challenge you to incorporate this TOPS model into your own teaching practice. Change it and make it better so it works for you.



1. SELECTION

Decide which of the 15 possible topics of study, A through O, you wish to study next. The alphabetical ordering, listed in the table of contents, is but one of many possible sequences. Your school's teaching syllabus might dictate a different arrangement. Better yet, let students decide what they want to study next. Consult "Sequencing" in the introduction to each topic, to determine what, if any, prerequisites must be completed first.

Once you have selected a topic, begin the individualized activity cycle. Students simply turn to the appropriate page in their *Student Reference Books* and complete each activity in sequence on their own papers. Teachers not wishing to use student reference books can also photocopy each activity in class quantities. The *Teacher Resource Manual* contains full-sized reproducible activity sheets for this purpose.

Those who finish a topic early should be encouraged to do original investigations that go beyond assigned activities. "Extension" sections in many of the teaching notes, plus "Further Study" listings in the introduction to each topic, provide creative jumping-off points to open-ended exploration.

2. ORIENTATION

Clear directions and detailed illustrations enable students to interpret worksheet instructions on their own. This allows students to start each activity when they are ready to start it, not when the teacher has time to explain it.

Identify poor readers in your class. When they ask, "What does this mean?" they may be asking in reality, "Will you please read these instructions aloud?" You can help poor readers by pairing them with good readers, by encouraging students to help each other.

Some activities deal with concepts that are especially difficult (often math-related). They require extra explanations that only a teacher can provide. Check the teaching notes under "Introduction" to see what teacher input, if any, is required. Just before your most advanced students start an activity that requires a special introduction, call a temporary halt to individual activity so you can teach your whole class at once. Students can then apply what you've taught them individually, as each one completes the activity.

3. INVESTIGATION

Worksheets structure independent class activity. Students do experiments as directed using simple materials stored on shelves and in boxes. The grids, rulers, or other graphics required for some experiments should be removed from the consumable *Student Cutout Booklets*. These may be conveniently stapled to the back of each student's science notebook or assignment folder.

Students should think and act on their own and help each other. You'll need to answer questions and provide assistance, to be sure, but do so only *after* students have first tried to solve their problems independently. Make a conscious effort to stay out of the center of attention.

As you teach each lesson from one year to the next, new and better ways of doing things will gradually become apparent. Be sure to record your own better ideas, as you think of them, on the same page as the rest of the teaching notes. There is ample white space on each page for this purpose.

4. WRITE-UP

Activity sheets ask students to explain the how and why of things. Students respond on their own papers, never in the *Student Reference Book*. Reference books are for reading *only*. They will last many years if you take proper care of them. They are a welcome low-cost alternative to expensive photocopying.

Keep all write-ups on file in class. Notebooks, copybooks or file folders all serve as suitable assignment organizers. Students will feel pride and accomplishment as they see their file folders grow heavy, or their notebooks fill up, with completed assignments. Having all papers in one place also facilitates easy reference and convenient review.

Ask students to make an assignment record and staple it to the front of each notebook or file folder. They should list all 100 lessons in alphabetical order (from A-1 to O-5), on a single sheet of lined paper in 3 or 4 columns. As students complete each assignment, you simply initial your approval next to the corresponding assignment number. This record tells you at a glance if each student is working on schedule.

5. CHECK POINT

As lessons are completed, students should bring their personal write-ups to you for evaluation. (Make a class rule that the next activity should not be started until you have initialed your approval of the last one on their assignment records.) The student and teacher then evaluate these write-ups together on a pass/no-pass basis. You'll find an answer key for each lesson listed under "Check Point" in the teaching notes.

Because students are present when you evaluate, feedback is immediate and effective. A few seconds of direct student-teacher interaction is surely more effective than 5 minutes worth of margin notes that students may or may not read. Remember, you don't have to point out every error. Zero in on particulars.

If answers are wrong or write-ups are incomplete, direct students to make specific improvements. They should see you again for another check point when these improvements have been made.

6. SCIENCE CONFERENCE

Set a limit to the number of days you'll dedicate to individualized process science (usually 1 day per lesson). Announce the deadline for turning in all assignments well in advance. This gives your class sufficient warning to make an extra effort to get everything turned in on time. Not everyone will meet your deadline, of course. Too bad. Individualized activity has ended.

Science Conference is a time for students to come together, to discuss experimental results, to debate and draw conclusions. Those who did original investigations or made unusual discoveries share this information with their peers, just like scientists at a real conference.

This is also a good time to consider the technological and social implications of the topic you are studying. Invite speakers from your community to come in and talk to your class. Read and discuss newspaper articles of interest. Show relevant films. Consider possible resources available in your school and wider community, then bring them together.

7. READ AND REVIEW

Does your school have an adopted science textbook? Do parts of your science syllabus still need to be covered? Now is the time to integrate other traditional science resources into the overall program.

Your students already share a common background of hands-on lab work. They have discussed relevant social issues. With this shared base of experience, they can now read the text with greater understanding, think and problem solve more successfully, and communicate more effectively.

You might spend just a day on this step or an entire week. It all depends on your particular teaching style, the concepts you wish to cover and the resources you have available. The introduction to each topic contains a page of suggested evaluation questions. Keep these questions (plus others of your own choosing) firmly in mind as you review key concepts in preparation for the exam that follows.

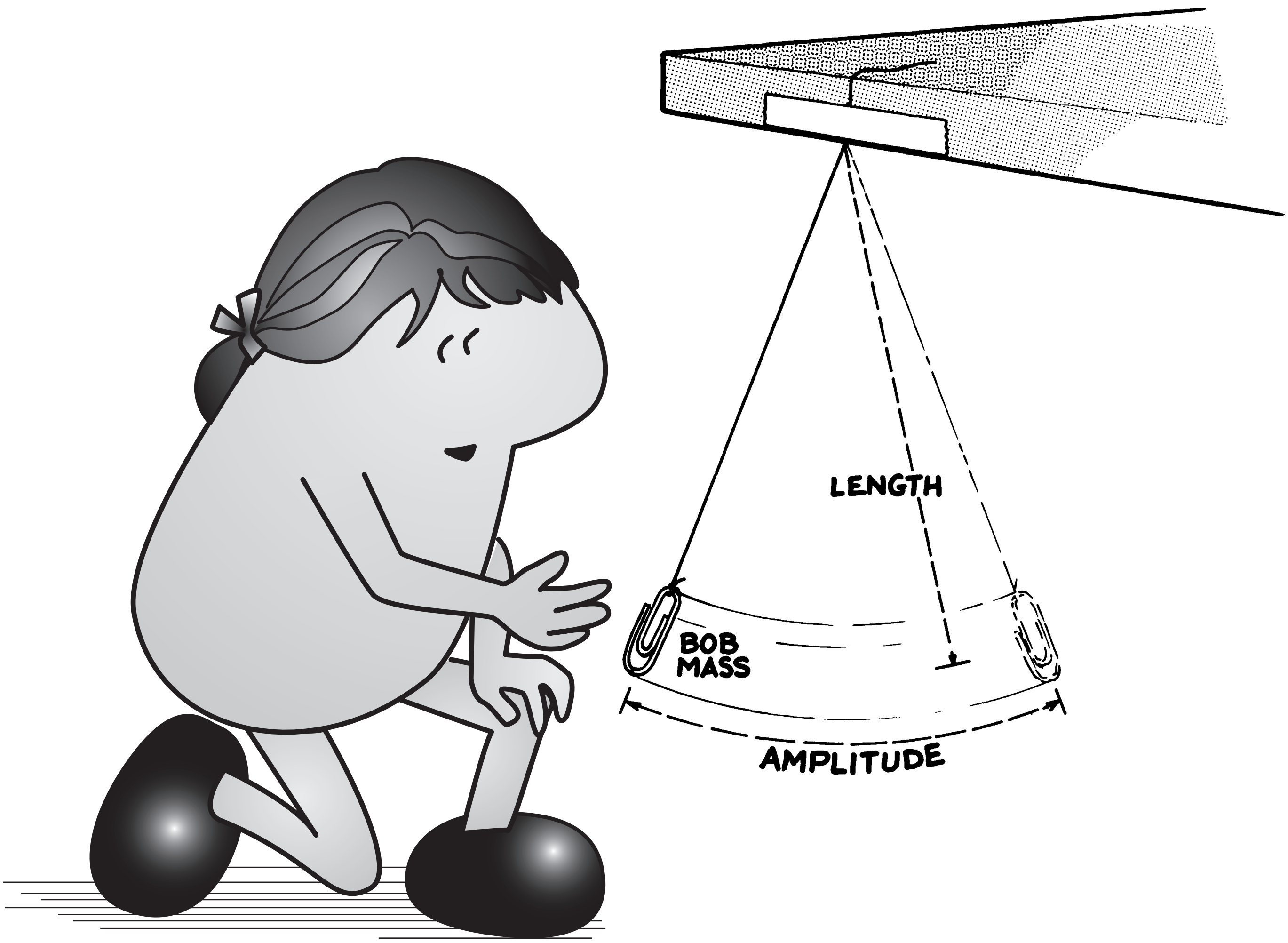
8. EXAM

Use any combination of test questions, plus questions of your own, to determine how well students have mastered the concepts you've been teaching. Students who finish your exam early might begin work on the first activity in the next new topic.

Base your overall grade on each student's overall performance. We recommend that you give these 3 evaluation components equal weight: (1) Effort: How many assignments received your check-point approval? (2) Attitude: Did the student participate actively or simply waste time and copy the results of someone else? (3) Achievement: How well did each student demonstrate mastery on the test just completed?

Now that your class has completed a major TOPS learning cycle, it's time to start again with a brand new topic. This is an opportunity to start fresh, to learn from past mistakes, to do better than before. Because each topic is relatively short, your teaching tempo remains brisk and lively; no chance for students to procrastinate or get bored. The frequent change of pace insures that your students will work hard, love what they learn, and grow in scientific literacy.

A. INVESTIGATING PENDULUMS



Pendulums are easy to build, as easy as tying thread to a paper clip. They swing back and forth with great regularity, measuring time in clockwork fashion.

Galileo is credited with first discovering that neither the mass of a pendulum's bob, nor its amplitude affect how fast a pendulum swings. Length is the only variable that matters. In these experiments, your students will follow Galileo's good example. They will learn all about pendulums, not by reading what other great scientists have done, but by doing great science themselves.

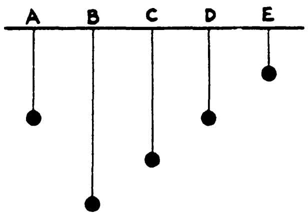
Finally your students will link pendulums together, then observe how they transfer kinetic energy from one pendulum bob to the other. This behavior is not at all intuitive. Pendulums surprise us by *not* doing what we think they should, and *not* doing it consistently. They teach us to observe the way things are, not the way we think they should be.

EVALUATION

Each question evaluates a single activity from INVESTIGATING PENDULUMS as numbered. Use any combination to frame a formal exam or an informal review: Copy these questions on your blackboard, construct your own ditto master, or photocopy the questions while masking out the rest of the page. Evaluate in ways that suit your own teaching style, enabling your students to learn and enjoy science.

Questions

A-1



a. Which pendulum swings fastest?

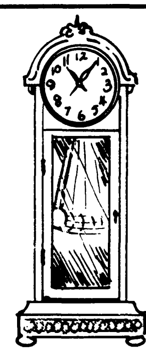
b. Which pendulums swing together?

c. Which pendulum swings slowest?

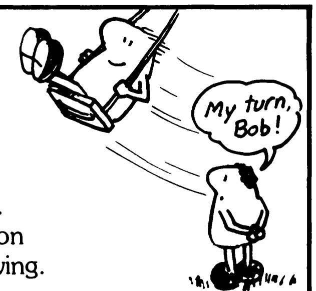
A-2

Your grandfather clock runs too slow.

How would you adjust the clock's pendulum to make it keep better time?



A-3

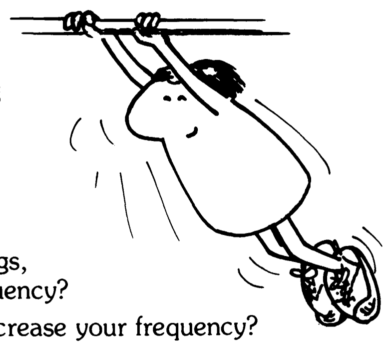


A heavy person swings on a swing in the park. Then a light person uses the *same* swing.

Do both people swing at the same frequency? Explain.

A-4

Suppose you are swinging from an overhead bar.



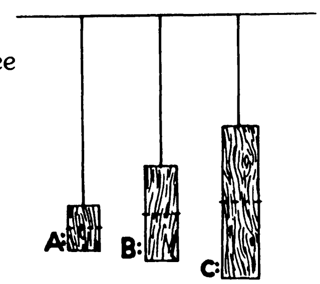
a. If you took bigger swings, could you slow your frequency?

b. How could you best increase your frequency?

A-5

Suppose you hang three strips of wood from a table like this.

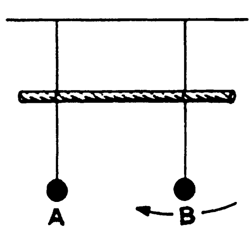
Which one swings the fastest? Why?



A-6

Two pendulums with equal lengths are taped to a long straw like this.

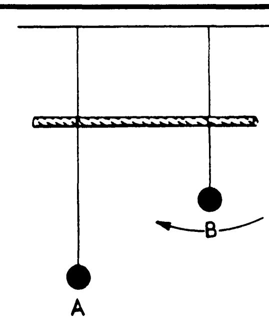
If you start B swinging toward A, predict what happens.



A-7

Two pendulums with different lengths are taped to a long straw like this.

If you start B swinging toward A, predict what happens.



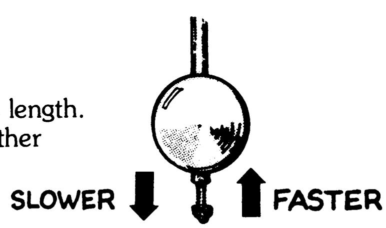
Answers

A-1

a. E b. A and D c. B

A-2

Shorten the pendulum's length. This makes the grandfather clock tick faster.



(Many pendulum clocks have an adjustable screw below the bob that allows you to make slight changes in the overall effective length.)

A-3

Yes, both swing at the same frequency. The swing moves like a pendulum. Its frequency changes only with length, not bob weight (the weight of the person using the swing).

A-4

a. No. The frequency of your body, swinging like a pendulum, does not vary significantly with amplitude.

b. Draw your legs up near your stomach to shorten your overall length.

A-5

Pendulum C swings the fastest. Its length, as measured from the pivot to the *center* of the wooden bob, is the shortest.

A-6

Pendulum B pushes against the straw and begins to transfer its energy of motion through the straw to pendulum A. A swings with greater and greater amplitude until it reaches a maximum, while B slows to a standstill. Then the process reverses and A transfers its energy back to B.

A-7

Pendulum B pushes against the straw and begins to transfer its energy of motion through the straw to pendulum A. But A has a lower frequency than B and soon gets out of phase. So A transfers the energy back again without reaching its maximum amplitude. In effect, B swings continuously while A starts and stops.

SEQUENCING

INVESTIGATING PENDULUMS is a good place to begin. The activities are easy to do and lead logically into B. Material requirements are extremely modest and easy to organize.

Related Activities: **A**---B

MATERIALS

Here is everything your students will use for the next 7 activities on INVESTIGATING PENDULUMS. Materials printed in normal type are part of the core 15-things-in-a-box inventory that support all 100 activities. Materials printed in *italics* are additional local materials that you provide or ask your students to bring from home. Pencil and paper are already assumed and therefore unlisted. Each item is numbered with the activity where it is first used.

(A-1) Thread. Don't substitute string.
(A-1) Scissors.
(A-1) Paper clips of uniform size and weight.
(A-1) Masking tape. Don't substitute clear tape. It's too hard to see and clings tenaciously to desk surfaces. This makes clean-up difficult.
(A-2) A *wall clock* with second-hand sweep. Your students can also use wristwatches if they have them.
(A-6) Rubber bands.
(A-6) *Small coins* of equal size.

FURTHER STUDY

Use problems like these plus "extension" ideas in INVESTIGATING PENDULUMS to lead your students beyond worksheet activity into original research and investigation. Each discovery leads to more questions, deeper questions, better questions than these. Answering them is what good science is all about.

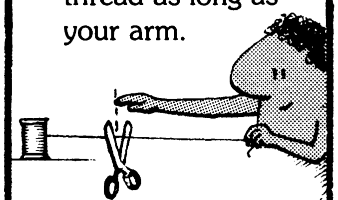
Read about the history of time in an encyclopedia. Sketch examples of different types of early clocks, showing how they worked. Did our ancestors use other things besides pendulums to keep time? Build a clock of your own as a science project.

In politics you hear that the pendulum has "swung in the other direction" or that "events have come full circle". Do you think that history, like the pendulum, repeats itself? Write an argument supporting your position.

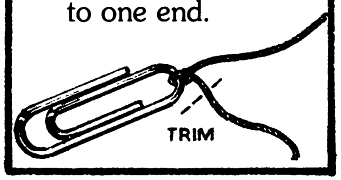
Do you like to ready scary stories? Edgar Allen Poe, an American writer of the early 19th Century, was a master of the macabre. Go to the library and read one of his more famous short stories "*The Pit and the Pendulum*". Write a book report.

OBSERVING PENDULUMS

1 Cut a piece of thread as long as your arm.

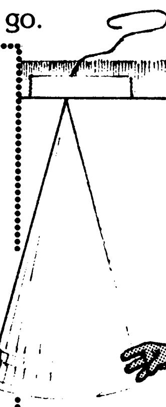


Tie a paper clip to one end.



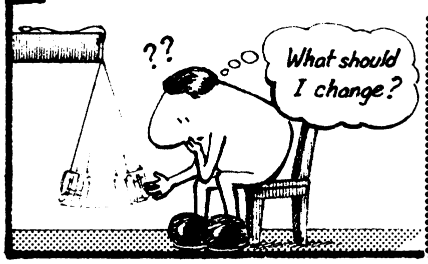
2 Tape it to the bottom edge of your table like this.

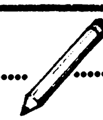
3 Pull the paper clip to one side, then let it go.



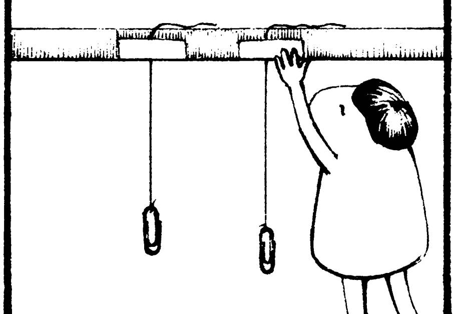
Describe how the paper clip moves.

4 Find a way to make your pendulum swing faster; then slower. Tell how you did this.





5 Hang another pendulum next to your first.

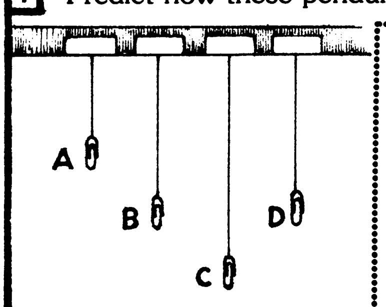


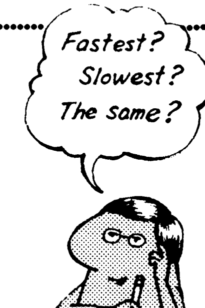
6 Make both pendulums "march together" for at least 10 cycles back and forth.

☐ TEACHER CHECK

Tell how you did this.

7 Predict how these pendulums will swing. Give reasons for each answer.





Objective

To observe a pendulum and describe its motion. To understand, in qualitative terms, how the frequency of a pendulum changes with length.

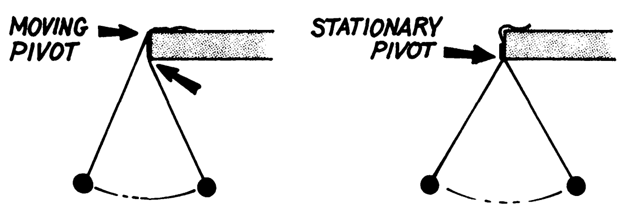
Introduction

The activity sheets in this book are reproducible, should you elect to photocopy. There is, however, a more economical hassle-free approach. Give your class a set of *Student Reference Books* instead. Remind them that these books are for reference only — to be shared by everybody — now and in years to come. No writing or cutting allowed! Students respond on their own assignment papers and cut out the required graphics from their own consumable *Student Cutouts Booklets.*

Lesson Notes

1. Young children may experience difficulty when attempting to knot thin wispy thread. Remind them to use 2 loops, not 1. Explain that big loops are easier to tie than small loops. Identify students who are good at tying knots, and ask them to help those who have difficulty.

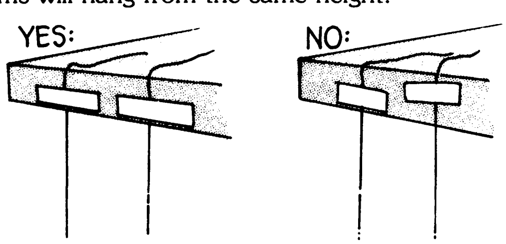
2. Some students may tape the pendulum to the *top* surface of the table rather than the *edge*. From a practical point of view this is OK. Experimental results are not the least bit affected. However, there is a technical reason for using the edge. This gives the pendulum a single stationary pivot. Notice how the pivot jumps back and forth between two different points when the thread is taped to the top table surface.



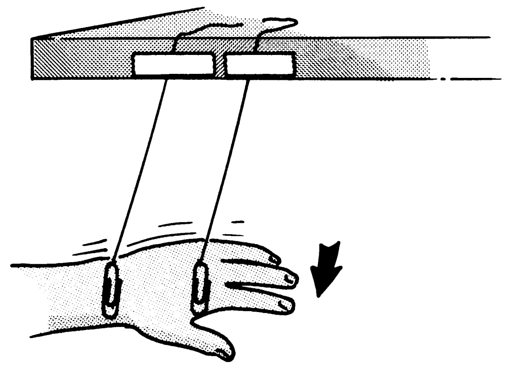
4. To lengthen or shorten the pendulum, simply pull the thread *through* the tape. Students don't need to reposition the tape, although some may do so.

Allow students to discover the relationship between length and frequency in their own good time. Don't rob them of the joy of discovery by telling them the "correct" answer before they've had a chance to do their own experimenting.

5. Bring the second piece of tape even with the first, flush with the bottom edge of the table. This insures that both pendulums will hang from the same height.



6. An easy way to start both paper clips simultaneously is to release them from a ruler, a book, or the back of your hand.



It is not possible, of course, to make pendulums (or anything else) *exactly* the same length. The best students can do is stay within a specified tolerance. In this case the lengths must be adjusted so nearly equal that the pendulums still remain "in step" after ten cycles. This demands very subtle length adjustments. As your students struggle to do this, they'll appreciate first-hand the sensitive interdependence between pendulum length and frequency.

Those who can't meet this tolerance might be directed to use longer pendulums. (Long pendulums are less sensitive to subtle changes in length than shorter pendulums.) Since *you* administer the teacher check, *you* decide when each student has done his or her best and earned the privilege to move on to step 7.

7. Make sure your class understands what it means to "predict". (Make an educated guess based on previous experience.) If students are unsure of their predictions, or have guessed wrong, ask them to actually set up the pendulums as illustrated and check their answers.

Extension

Hold a class contest to see who constructed the best pendulum pair. Ask everyone to release their pendulums at the same time. You, or a group of student judges then identify those pairs that remain in step over the longest time. Match these finalists against each other to determine a class champion.

Check Point

3. The paper clip swings back and forth through an arc. It moves fastest through the bottom of its arc, slows to a complete stop at the top, then accelerates back down in the opposite direction. (The paper clip also describes an ellipse when swung in a circle.)

4. To make a pendulum swing faster, decrease its length; to slow a pendulum, increase its length.

6. Adjust each pendulum until they have the same length.

7. Pendulum A swings fastest. Pendulum C swings slowest. Pendulums B and D swing with the same frequency.