If You Build It, They Will Learn

17 Devices for Demonstrating Physical Science

by Bruce Yeany

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Preface

Science supply companies offer more materials than a classroom could possibly use, so why would any teacher want to build his or her own demonstration pieces? For starters, some of you may have problems with equipment cost, quality, size for classroom needs, and availability of a product. Or you may want to be able to adjust variables to meet specific student needs and to gain a sense of accomplishment when you complete the task. You will find using pieces of equipment you have built for yourself extremely satisfying, and you may gain a deeper understanding of the concepts you want to teach. Perhaps most important, building or having students build equipment helps create an environment rich in opportunities for students to make observations and investigate ideas.

When I've demonstrated the devices in this book at workshops and inservice programs, I've found many people who want to make their own equipment but are lacking in two fundamental areas: how to construct and how to use the equipment within the classroom setting. This book addresses those areas.

Step-by-step directions for the device are given in the second part of each section—"Directions for Assembly." Some of you may find the building section more detailed than you need, but I want to be sure anyone can make these devices—even those who are unaccustomed to building these types of projects. If you lack any of the tools or skills needed, look for help from a variety of people—students, friends, parents, or other teachers, possibly those who are in the school shop programs.

Once the equipment is built, you will need to know the best way to use it. Each section starts with suggestions for instruction—"Instructional Information." Good demonstrations and activities need the proper groundwork laid before they are used. You must verify that students are learning the concepts set out as the objective during and after each demonstration is performed in the classroom, and this part will help you do that. You will probably want to add ideas of your own.

Bruce Yeany

Why Build It?

Demonstrations and equipment should continue to play a role in the acquisition of knowledge. Research overwhelmingly supports using materials that can help discover or redefine how the processes of science operate. What is also clear is that teachers must use demonstration and exploratory materials with a clear, well-thought-out purpose in mind. The days of unconnected demonstrations for the fun of it are gone.

You need to establish what knowledge students already possess and then determine what methods will build effectively on the established base. In some cases, you should use inquiry and discovery methods before discussing concepts. Or you could use lecture demonstrations followed by activities that would clarify the conceptual knowledge.

You must make sure that students are not passive learners, whatever your method of instruction. Students must be involved, whether through hands-on activities, diagramming, interactive discussions, Socratic questioning, or other techniques.

Research reaffirms that science can be as interesting as we want it to be. A classroom filled with materials to explore will spark a student's interest in the subject matter. The moment students walk into your room, something should prod them on to further studies. A science room indistinguishable from any other classroom can impart only a neutral or even negative attitude toward the subject matter. This not only makes the teacher's job harder, but also can determine the degree of success students will have within your classroom.

Improving Learning Through Demonstrations

There is strong pedagogical argument to be made in favor of using demonstrations in the classroom. If the demonstration is going to achieve any of the lofty goals that the National Science Education Standards (NRC 1996) have described, however, it must be carried out effectively. Here are a few guidelines that can increase the effectiveness of equipment and teacher demonstrations.

- Present real science, not a sideshow. Demonstrations should serve serious educational purposes. Avoid demonstrations in which the concepts will not be studied.
- Keep demonstrations as simple as possible while still making your point. Complex demonstrations tend to confuse students and may lead to reinforcing misconceptions.
- Use examples that students can relate to. Concepts are easier to understand when students are familiar with the demonstrated materials.
- Encourage students to try experiments for themselves. Give them opportunities for additional research and exploration.
- Have students predict the outcomes of a demonstration by themselves and then have them discuss their predictions with other students before seeing the demonstration.

- Use discrepant events sparingly. Don't leave discrepant events as a misconception; make sure students understand the concept before continuing.
- Have students explain their observations to others.
- Ask questions of students and encourage them to ask questions of you. Ask students to explain what they saw. Have students use diagrams to illustrate the demonstrated concept.
- Have students observe, write, and explain. Students need to show understanding of concepts. Do not assume that they "got it."
- Make the demonstration visible. If students cannot see what happens, there is no reason to demonstrate.
- Do not be afraid of failure. An experiment that does not work can be a learning experience.
- Keep demonstration pieces in plain view. Too many pieces of equipment stay locked up in closets, never to see the light of day, or are shown only for brief periods. Keep your demonstration pieces out for days after a demonstration.

Classroom Guidelines

Each of the devices in this book is in a single section consisting of two parts "Instructional Information," and "Directions for Assembly."

"Instructional Information," the first part of each section, reviews the intended concept and how it can be presented in the classroom setting. "Instructional Information" includes explanations and examples and may list brief instructions for creating additional activities. This part is broken down and labeled with the following subheadings.

Picture and Overview

Each chapter starts with a photo or photos of the completed device. The overview briefly describes the concept demonstrated by each piece and how the device can be used.

Student Skills

Each device and its suggested additional activities offer the students a platform on which to build or "construct" several educational processes and skills. In many cases, the demonstrations are just the starting point for more advanced studies. To expand the demonstrations beyond the point of entertainment, you should identify what skills you want to concentrate on and then develop stronger lessons in those areas. One or more skills or processes related to the activity are listed under this subhead.

Related Concepts or Processes

This list suggests areas of study in which the device can be used. You can use it also as a list of vocabulary terms.

Prior Knowledge

The term *prior knowledge* is essential. Using demonstrations when students don't have a basis of understanding is merely entertainment. This section suggests underlying principles that will help students understand the device. The ideas listed are the concepts you can lay as groundwork for understanding for the ideas to follow. Without prior knowledge, demonstrations can promote or reinforce misconceptions that become harder to correct with the passage of time.

Predemonstration Discussion

This subhead is an extension of the prior knowledge subhead. Although it is difficult to suggest all possible scenarios that lead to the use of each device, this section reviews the most basic concepts. It contains questions that can be used for discussions and, in several cases, suggests activities that can review prior knowledge concepts. You can review quickly or extensively, depending on your classroom requirements. In either case, going over the concepts listed here will be beneficial to students when they view the demonstration.

Suggestions for Presentation

This subhead suggests methods for presenting the device and questions for discussion. The sequences of interactive questions will guide students to an understanding of the concept rather than their being dependent solely on instructor explanations. The questions will promote discussions about the action of each device. You should develop additional questions that apply to your specific objectives. The intent of questions is to have students arrive at their own understanding and then demonstrate understanding by answering questions. You should listen carefully through the questioning process to determine that students have reached the level of knowledge they need. It is better to ask too many questions rather than too few. Many times we as instructors assume that students have grasped the concept only to find out later that they have missed central points of a demonstration.

Postdemonstration Activities

This segment offers additional methods for exploring the central concepts given in the primary demonstration. It may include additional questions for discussion, opportunities for writing prompts, variations of the demonstration, and additional experiments to try.

Discussion of Results

The discussion of results is intended primarily for you. It is a brief explanation of what the device does and how it works. It explains the concept that is demonstrated. You can modify the explanation to the level you want for your students.

Additional Activities

This segment offers additional pieces or activities for further study. Students can explore some of the ideas offered in this section on their own as a science project or as an independent study.

Reference

National Research Council (NRC). 1996. National Science Education Standards. Washington, DC: National Academy Press. Online version at *www.nap.edu/books/0309053269/html/index.html*.

Building the Device

"Directions for Assembly," the second part of each section gives a detailed, illustrated procedure on how to build each demonstration piece. In chapters in which directions for more than one piece are given, each is listed separately. This part of each section has two segments.

Materials

Everything needed to build the device is listed here. Common items such as varnish and tape may be omitted.

Directions for Assembly

This section is a step-by-step guide that explains in detail how to build each piece. Pictures and drawings have been included as visual aids. These pieces have been constructed using the minimum number of tools. In many cases, the wood dimensions are matched to existing purchased wood widths. The dimensions in these pieces are not critical and can be changed to fit available supplies. You don't need a complete woodshop to produce the devices. The list of power tools has been kept to a minimum, but they would make the production easier. Please refer to the manufacturer's instructions for proper and safe use of each tool listed.

Suggested Tools

- Drill with a set of drill bits—a counter sink for screws would also be very useful
- Screwdrivers, Phillips and slotted blade
- Saw—many options here include handsaw, circular saw, miter box, saber saw, band saw, and table saw
- Balance or spring scale
- Sander—a powered hand sander or belt sander would be helpful but is not required
- Propane torch or other heat source
- Carpenter's square
- Pencil
- Scissors
- Sandpaper, medium to fine grit
- Paintbrush

Safety First

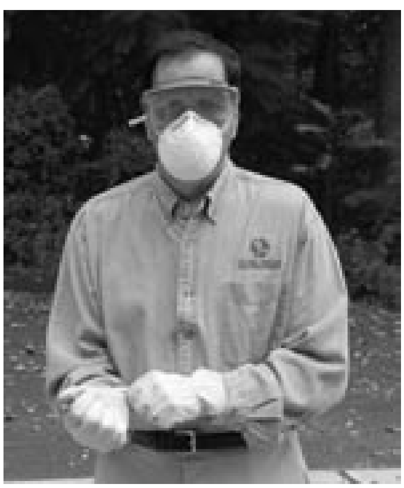
Safety should be everyone's first concern, whether it's in the classroom with students or in the workshop preparing materials for use in the classroom. Safety notes accompany each piece. Pay attention to them.

Equipment

The safety equipment shown here is inexpensive and may save you from a trip to the doctor.

The type of goggles shown provides protection from flying objects and from irritating dust particles. NSTA recommends that you use safety goggles that conform to the ANSI Z87.1 standard and that provide both impact and chemical-splash protection for all science laboratory work.

The dust mask provides good protection from breathing in dust particles while cutting or sanding; however, it is not adequate for blocking fumes from varnishing.



A long sleeved shirt and leather gloves complete the wardrobe for safety. The leather gloves are particularly useful when you are holding wooden parts during sawing, drilling, and sanding.

Whenever possible, cut, drill, and sand outside. It helps reduce the amount of sawdust that gets spread around inside the house.

Staining and varnishing of the finished pieces should be done outside to help reduce fumes inside the house.

Common Construction Practices

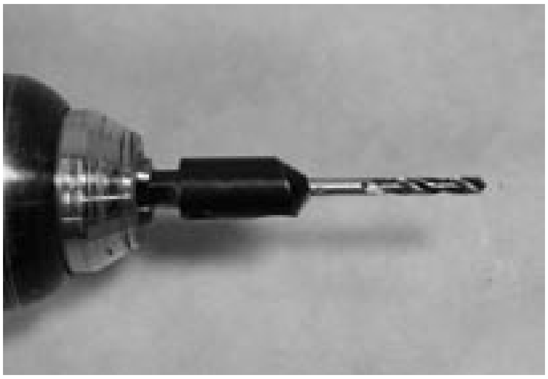
In some of the sections, photographs will show wood parts being held by hand during the cutting and drilling process. This was done only to make the instructions clear. It is not the best or safest method for construction.

Using a clamp or clamps is one alternative to holding parts by hand. Several types of clamps are available and can be found in most hardware stores. The wood is shown clamped down to a workstation. This is more secure and safe than holding it in your hand and will yield greater precision in cuts and drilled holes.

Using a vise is the safest and most secure method for holding pieces of wood during construction.

Clamping wood pieces in the vise can also be helpful when sanding. With the vise holding the wood securely, you smooth the edges with a sander while you use a hose from a vacuum to capture most of the dust particles.

Several of the devices need screws to hold pieces of wood together. A countersink drill bit is a cheap but practical purchase for use during the construction of these pieces.

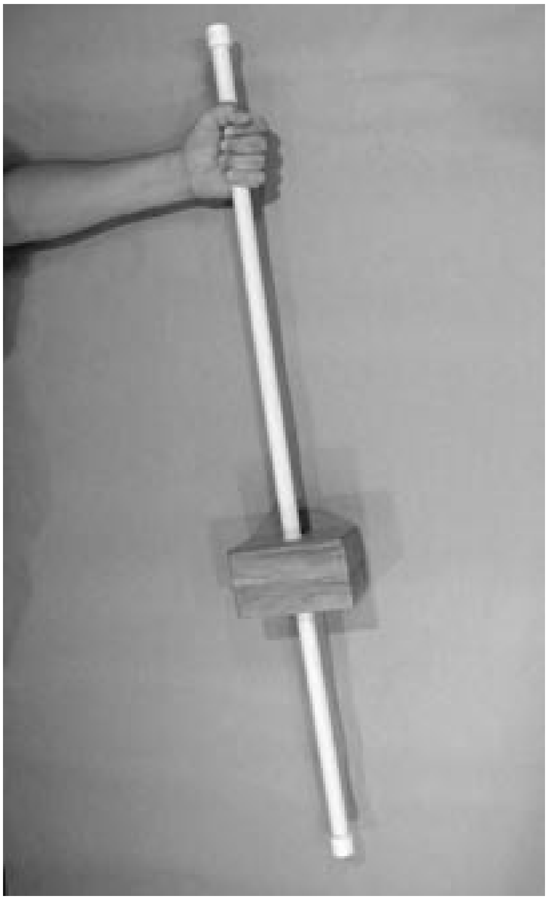


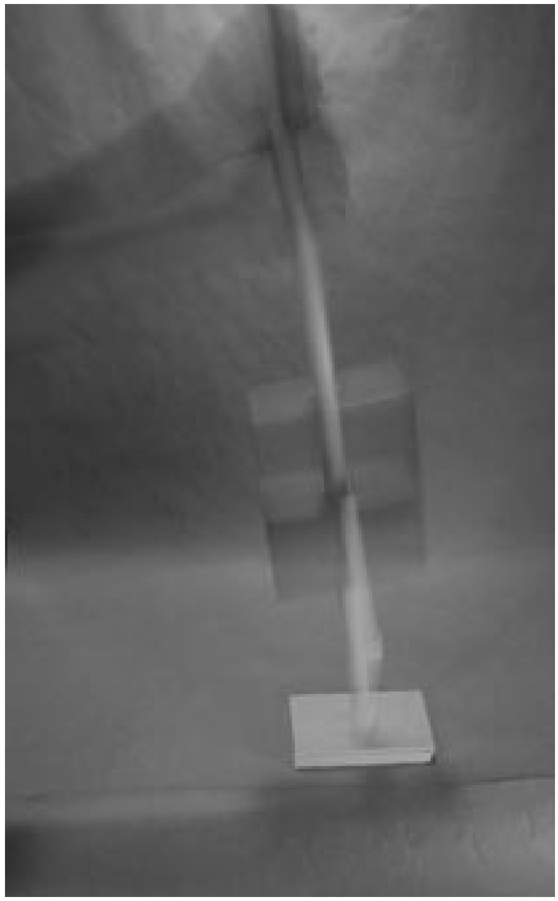
Screws put into an ordinary hole can split the wood due to the large screw-head size. The countersink drill bit will drill a hole for the shaft of the screw. The black portion of the countersink should be drilled into the wood deep enough to fit the head of the screw.

The face of the screw should be slightly beneath the surface of the wood into which it is screwed. This will keep the sharp edge of the screw head from scratching against other surfaces.

Sign your name! If you make the effort to build a project, take time to sign it and add the date. It adds a nice personal touch and you will appreciate it years later—as you can see from the photograph.

Instructional Information





Overview

Newton's first law of motion describes the resistance of an object to a change in the speed and direction of its motion. The law also holds that objects will resist being put into motion. This concept is described as inertia, and both aspects of the law can be demonstrated using this device, which is a heavy block with a hole through the center and one end of a plastic tube inserted into the hole. To demonstrate it, you will use a rubber hammer and hit the other end of the plastic tube with a succession of blows, causing the block to move toward the direction of the hammer with each blow. To show the second aspect of inertia, slide the block near the top of the tube. Hold the tube and block above a tabletop and move it rapidly toward this surface. When the tube strikes the table, it will stop, but the block will slide a short distance down the tube toward the table.

Inertia Block

Student Skills

Observation. Students can observe the action of the block when it is put into motion and the resistance to motion as the pipe is given swift taps by a hammer.

Research. Students can research the concept of inertia and its applications.

Application. Students should be able to identify and demonstrate many examples that illustrate the concept of inertia.

Related Concepts or Processes

Inertia	Impulse
Force	Friction
Mass	Balanced and unbalanced forces
Newton's first law of motion	Acceleration

Prior Knowledge

This device can be used to introduce or to reinforce the concept of inertia. In either case, students should understand some fundamental processes that apply to this demonstration. One concept is that force is applied as a push or a pull against an object, and forces are required to produce motion. Students should also have some ideas about friction as a resistance to motion. And, although students may not have been introduced formally to Newton's second law, they most likely have a basic intuitive understanding that there is a relationship among the amount of force applied, the mass of an object, and its acceleration.

Predemonstration Discussion

Any discussion before the demonstration should center on force, motion, and friction. Students should understand why an object accelerates or decelerates. Review with them that any change in velocity occurs because of an unbalanced force that is opposite to the velocity of the object.

Questions to discuss could include the following:

- Why do objects move?
- Can objects ever move by themselves?
- What are some types or examples of objects that can move by themselves? How do these objects accomplish this?
- What are some types or examples of objects that cannot move by themselves? What is needed to put these objects in motion?
- What is the result of balanced forces?
- What is the result of unbalanced forces?
- What happens to the motion of an object when a force stops being applied to it?
- What is it that causes an object to slow down?

Suggestions for Presentation

If students have no previous experience with inertia and Newton's first law of motion, they can learn the concept as you demonstrate the device. If you use good questioning techniques, the students can determine for themselves what the principle or concept is that is being demonstrated. If students already have an understanding of Newton's law, then you can use this piece to review the concept. Newton's law is described in two parts: The first part predicts the behavior of stationary objects, and the second predicts the behavior of moving objects.

Part One

Start with the block located somewhere near the middle of the tube. Using a bit of showmanship, exaggerate the force needed and slide the block to that position. Show this action to the students, giving them a visual cue that the block can move on the tube. Wave the block and tube up in the air and gently move the block forward and backward showing that the block has enough friction on the tube that it does not slide easily.

Hold the tube vertically with the block at the bottom end and your hand near the top of the tube. Use a rubber mallet or similar soft object to hit the top end cap with quick successive blows. The block will slowly climb up the tube and eventually reach your hand. As you hit the top of the tube, try not to hold the tube too rigidly, but rather allow it to move in small increments from the hammer blows.

The orientation of the demonstration can be changed. Try the same process holding the device sideways or upside down.

Interactive questions during presentation could include the following:

- Which is easier to move, an object with only a small mass or one that has a lot of mass?
- What is needed to make an object move?
- My hand is holding the tube, but what happens to the tube as I hit it?
- If the stick is moved a short quick distance when I hit it, is the block moving also?
- If I were to hit the stick harder, how might this affect the distance the tube moves through the block?
- Do you think it would make a difference if we held this tube in another direction such as sideways or upside down? Why would we need fewer blows if we tried this upside down or sideways?

Part Two

To demonstrate the second part of Newton's law of motion, the block should be positioned at an end of the tube. Hold the tube vertically with the block positioned at the top end of the tube. Holding the tube above a tabletop, swing it straight down and have the bottom end of the tube strike a hard surface such as the tabletop or the floor. The purpose is to stop the tube very abruptly. The block will slide down the tube for a short distance. Repeating this step will drive the block downward with each successive blow; the distance the block moves with each blow will depend on the speed of the swinging movement and the amount of friction between the blocks and the tube. The orientation of the demonstration can be changed. Try the same procedure with the tube held sideways and strike the tube against a wall. This can even be tried with the assembly moving upward if there is a suitable surface to hit. My preferred location is swinging upward in the doorway and hitting the top of the door frame.

Interactive questions during presentation could include the following:

- After the block is put into motion, and the tube stops, what direction does the block continue to travel toward?
- Is it gravity that makes the block move down the tube?
- Why does the block move part way down the tube?
- What is causing the block to stop?

- If I were to swing the block and tube down faster, how might this affect the distance the block moves down the tube?
- Do you think it would make a difference if we were to move the block and tube in another direction such as sideways or upside down?
- Why would we need more blows if we tried this going upward instead of down?

Postdemonstration Activities and Discussion

A few writing prompts and ideas to research might include the following:

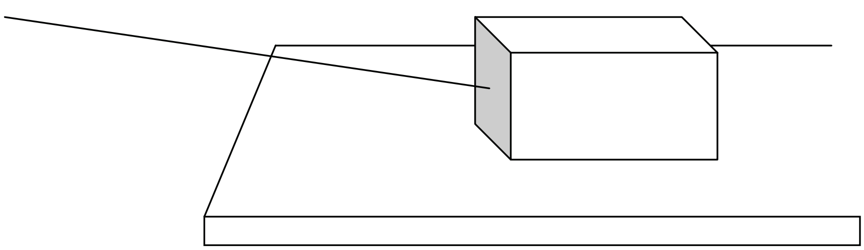
- How would either part of this demonstration change if the block had more mass or less mass?
- The block and tube are in motion; how would this experiment change if there were more friction between the block and tube?
- The block and tube are in motion; how would this experiment change as we decreased the amount of friction between the block and tube?
- How would the experiment change if there were no friction between the block and tube?
- What direction and how far would the block travel if there were no friction to stop it?
- Inertia is a favorite topic in most science classrooms and can be demonstrated in a variety of ways. Have students research other examples and perform additional demonstrations.
- Have students draw up two separate lists of ordinary occurrences that demonstrate part one or part two of Newton's law of inertia.
- Students can research the lives of Galileo and Newton.
- Students can research the reasons why seat belts and air bags are used in cars.

Additional Activities

There are many good examples for demonstrating Newton's first law of motion.

One of the best known is yanking a tablecloth from under a setting of plates and glasses on a table. Unfortunately, this demonstration has a high rate of failure when the tablecloth has a hem. The dishes and glasses get caught by the hem and fall over. You can try it using a large sheet of paper instead of the tablecloth.

One of the simplest and most effective demonstrations for showing inertia can be done with a heavy weight and a thin piece of string or thread. Fasten the string to the block, either by tying it into a hook or around the block.

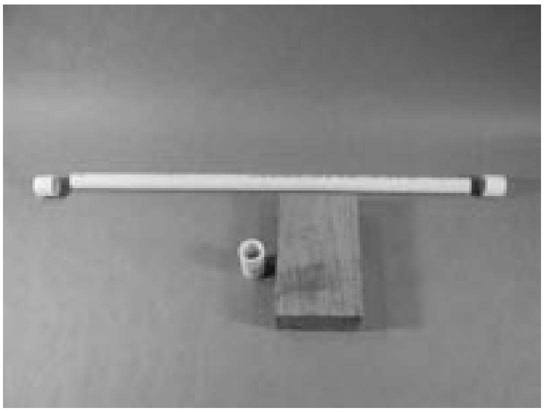


The string can be pulled slowly and the block will move. What will happen if the string is pulled very quickly? The block will resist accelerating and the string will break, following Newton's first law, part one.

If the block is put into motion and the thread is used to try to stop the block, the thread will break and the block will keep sliding for a short distance. This demonstration is an example of the second part of Newton's first law.

Students can try making their own version of the inertia block using a ¼-inch-diameter wood dowel and a piece of vegetable or fruit such as an apple. They should push the stick through the core of the apple and then follow the same directions given for the device.

Directions for Assembly



Inertia Block

Materials

- 1 wooden block, 4 in. × 4 in., thickness may vary from 2 in. to 6 in. due to available materials
- epoxy glue
- wood varnish
- 1 PVC pipe, ½ in. diameter × 3 feet
- 2 PVC end caps for ½ in. pipe
- 1 PVC coupler for ½ in. pipe

SAFETY NOTE

For this series of instructions, the following safety equipment is strongly recommended:

- Goggles for eye protection. NSTA recommends that you use safety goggles that conform to the ANSI Z87.1 standard and that provide both impact and chemical-splash protection for all science laboratory work.
- Dust mask to guard against breathing in airborne sawdust.
- Gloves whenever power tools are used.

Directions

1. The effectiveness of this demonstration depends on the block having sufficient mass. Hardwoods such as oak or maple will work better than pine. The wooden block dimensions should be approximately 4 inches by 4 inches by 2 or more inches. If thin wood is available, glue the pieces together to get the proper thickness.

   Draw lines from each opposing corner to determine the center of the block. After locating the center, use a wood bit that is approximately the same size as the outside diameter of the PVC couplers and drill a hole through the center of the block.

2. The coupler should fit snugly into the hole drilled in the block. The end cap will occasionally hit this coupler during the operation. It will become dislodged if it is not securely attached within the block. If the connector is too tight to push in by hand, tap it with a wooden block to push it into place.

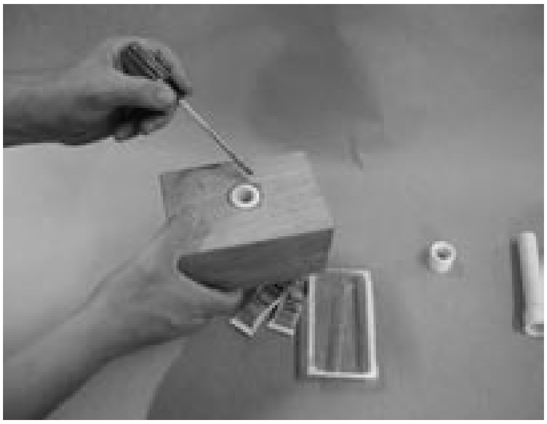
3. If the drilled hole is not quite large enough, sand the inside of the drilled hole until it is the right size. To do so, wrap a piece of sandpaper around a wooden dowel and use a rubber band to hold it in place. This sanding stick can be used with the drill to sand the inside of the block. Use the drill on high speed to get a smooth, rounded hole.

4. If the block is more than ½ inch thicker than the coupler, use a small handsaw to cut the PVC connector in half so that you have 2 rings. You will set 1 piece of the connector into each side of the block. If the block is large enough, 2 whole couplers can be used.

5. Before the coupler is glued inside the block, there is a ring of plastic inside the connector that you need to sand off. Use the sandpaper wrapped around the dowel rod to sand the inside of the ring until the coupler can slide all the way through the PVC pipe with effort. Do not sand off too much: There must be some friction between the coupler and the pipe. If the fitting is too loose, the block will move on its own when the pipe is held vertically. Using the dowel on the drill is faster than sanding by hand.

6. If there is only 1 coupler to fit into the wooden block, apply some epoxy glue to the inside of the block and press the coupler into place and allow it to dry. If the connector is a tight fit, use a piece of wood to tap it into place.

   If you use more than 1 coupler, they will need to be glued into place one at a time. Start by gluing 1 half of the connector into 1 side of the wood.



7. Make sure that the edge of the coupler is flush with the block surface. Try to remove as much of the wet glue as possible before it dries on the wood surface. It is easy to remove glue while it is wet but not after it dries.

8. If 2 coupler pieces are needed, insert a piece of PVC piping through both couplers while gluing the second piece in place. This will help ensure they are aligned properly. Glue the other half of the coupler into the opposite side of the block. Once again make sure that the edge of the coupler is flush with the wooden surface.

   Sand the block to remove all traces of glue around the connector. If the coupler was not glued flush with the wood surface, the excess can also be sanded away.

9. After the glue has dried, the block should slide on the tube with some effort. If it is too hard to move the block, it can be made easier by sanding the inside of the PVC coupler. Do not make it too easy, or the demonstration will not work. Varnish the block to seal the wood and give it a nicer appearance.

10. The PVC piping usually comes with writing on it. Washing the PVC pipe with hot soapy water and scrubbing with a scouring pad can remove this and give the piece a nicer appearance.

    With the block on the tube, slide the end caps over each end of the tube. It is not necessary to glue the caps on.

11. The completed project.