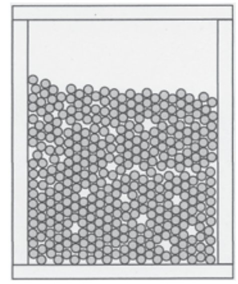
ICE Devices

The BB Board



Complex structures are understood better by using simple concrete models. The BB Board helps to show the atomic structure of solids. It can illustrate various types of crystal defects and can be used to demonstrate annealing, hardening, and tempering of steel. Instructions for assembling a BB Board are given, followed by suggestions for its use in demonstrating the nanoscale properties of metals.

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The BB Board

By Ron Perkins, Illustrations by Robert A. Shaner

Complex structures are understood better by using simple concrete models. The BB Board helps to show the atomic structure of solids. It can illustrate various types of crystal defects and can be used to demonstrate annealing, hardening, and tempering of steel.

Materials

__ *10″ × 15 1/2″ × 1/4″ sheet of acrylic plastic with square corners (for example, Plexiglas®), available from a hardware or home improvement store, or a plastics supply house (see step 1)*

__ *table saw (optional, see step 1)*

__ *file and sandpaper (see step 1)*

__ *10 mL acetone* OR 20 mL acrylic solvent such as "Plaskolite® Solvent Cement" (available from hardware stores or home improvement centers)*

__ *solvent applicator* ***if using acetone:*** *a small 10-mL syringe, a pipet, or a Q-tip cotton swab**
if using acrylic solvent: *10-mL syringe or eye dropper*

__ *about 1000 BB pellets †*

__ *sheet of stiff paper*

__ *about 6 binder clamps (office type) OR a vise*

Assembly Directions

1. It is best to let your plastics supplier cut the plastic sheet to the correct dimensions, listed below. If you need to do the cutting yourself, follow the suggestions here and use the layout shown on the next page.

   __ *2 pieces at 9″ × 7″ × 1/4″*

   __ *2 pieces at 3/8″ × 7″ × 1/4″*

   __ *2 pieces at 3/8″ × 8 1/4″ × 1/4″*

   If you use a table saw with a veneer blade or carbide blade designed for plastic, you will get fairly smooth edges. Otherwise use a band saw or a jig saw and follow by filing and polishing. When laying out the cutting pattern, allow at least 1/4″ for each cut for the width of the blade (kerf).

   Once the plastic is cut, sand or file any sharp edges by hand.

**** Acetone solvent:*** If using acetone as the solvent, see the note on the next page for a modified application procedure; a Q-tip swab works well as an applicator for the acetone. A dry Q-tip is also useful for cleaning up any extra solvent that gets on the edges.

† BB pellets: The BB pellets should be .177 caliber (the number of grains does not matter). They can be copper- or zinc-plated. BBs are readily and inexpensively available from a variety of sources including big box and sporting goods stores as well as online.

Directions If Using Acetone as the Solvent

Step 3 of the Assembly Directions details how to properly use a professional acrylic solvent cement. However, acetone is readily available in most chemistry laboratories and provides a convenient alternative. Acetone may be used to "weld" the layers of Plexiglas together: it dissolves the surface of the Plexiglas and as the acetone evaporates the acrylic recrystallizes and forms a physical bond between the layers. It can be applied using a small pipet, syringe, or a cotton Q-tip swab. Since acetone does not adhere as quickly as the acrylic solvent cement, minor modifications to the assembly procedure are needed: follow the procedure in steps 3–7 *with the modifications below.*

⚠ **CAUTION:** *acetone is highly flammable. All steps should be done in a well ventilated area.*

Make one joint at a time by positioning the Plexiglas pieces as in the directions below; to keep the pieces in place, clamp them together using a vise or binder clips.

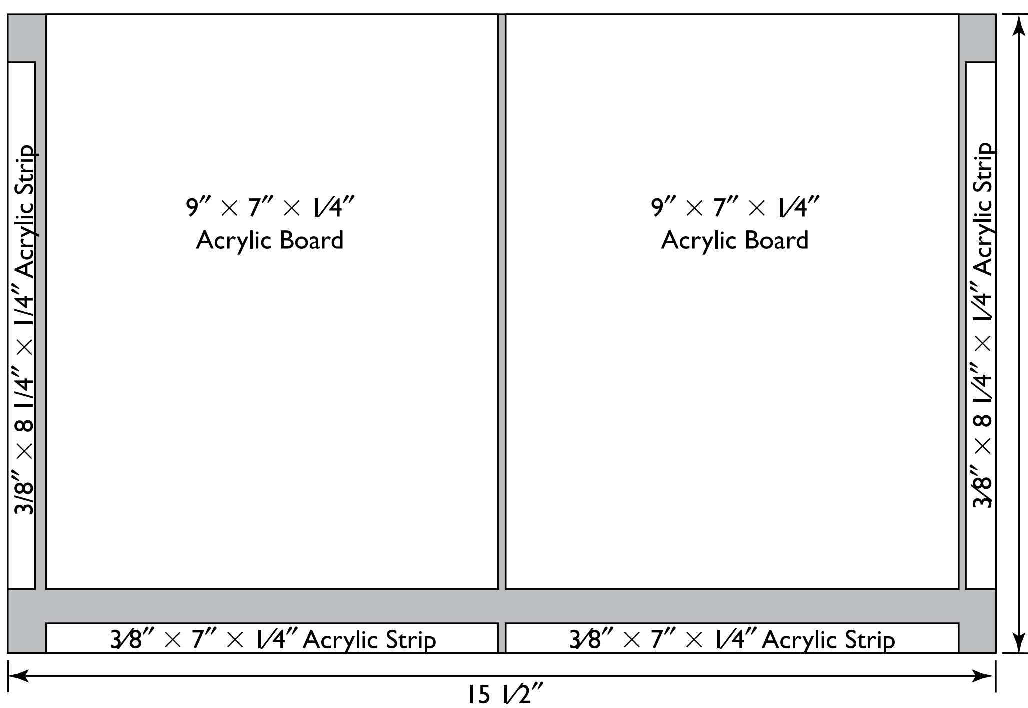
Apply a small amount of acetone to the outside adjoining edges using an applicator of choice (pipet, syringe, or Q-tip). The acetone will be drawn between the layers by capillary action—you should be able to see it wick through the layers.

Reapply acetone, if needed, *until you see that the acetone has been drawn all the way through the pieces you are welding together*.

Use a *dry* Q-tip swab to wipe down all the edges where acetone may have leaked through.

If the pieces need realignment, you can move them during the first minute (but if the pieces have not been moved, the seal will be transparent). The pieces will be sealed together when the acetone has evaporated completely—about 3–5 minutes.

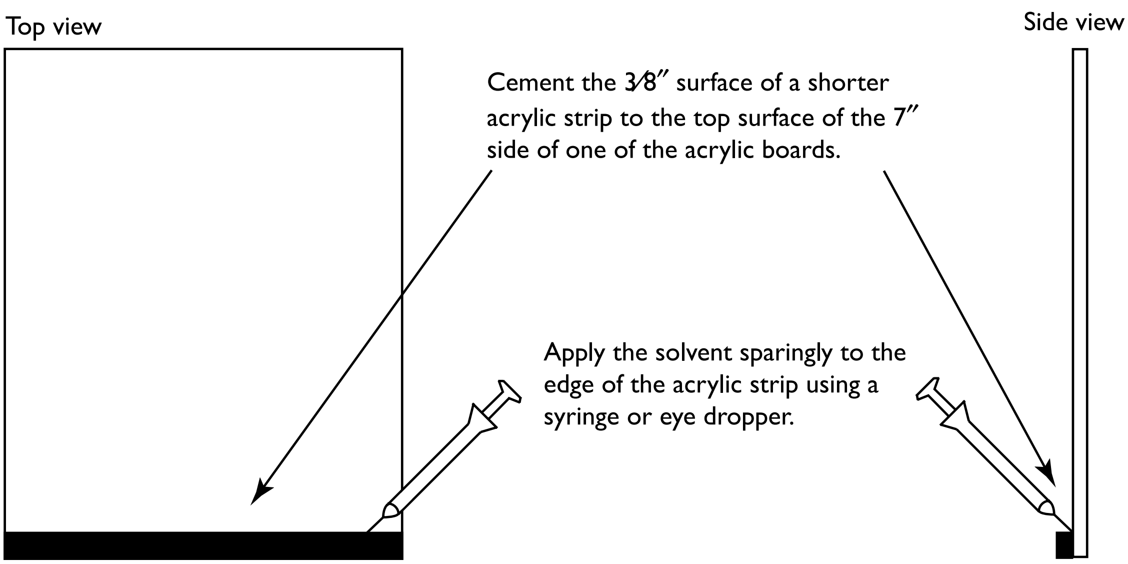
Layout for cutting plastic pieces for one BB Board (Scale: 1″ = 3″).



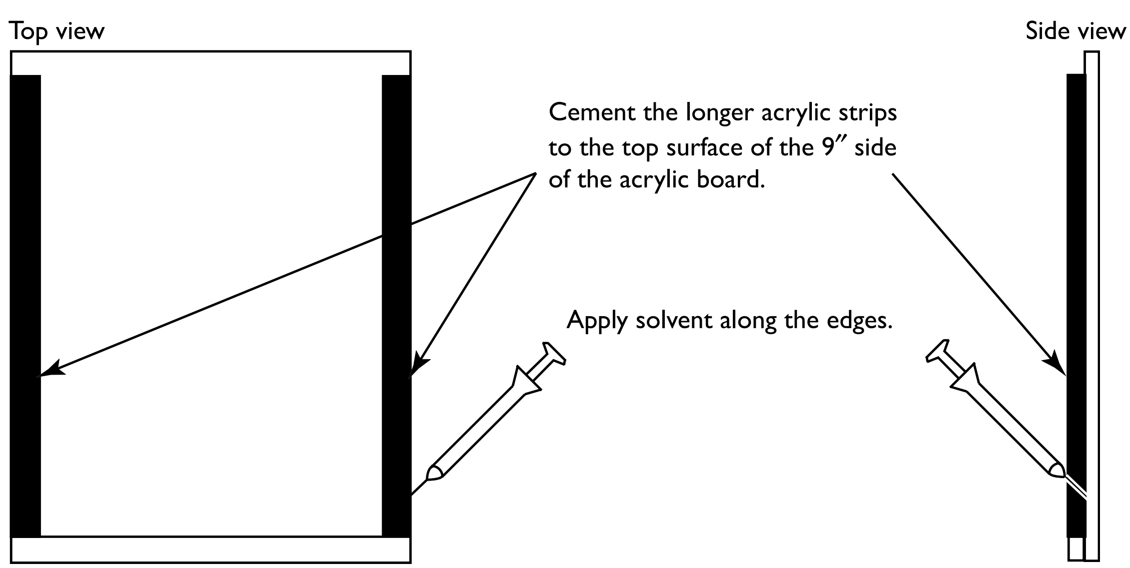
2. Remove the contact paper from **one** surface of each 9″ × 7″ board. Keep the contact paper on the bottom surface of each board to protect it from scratches. Remove all the contact paper from the narrow strips.

3. Place one of the shorter acrylic strips along the 7″ edge of the top surface of one 9″ × 7″ acrylic board, **with the 3/8″ surface side down**. Fill a 10-mL syringe or an eye dropper with the acrylic solvent. ⚠ *Use adequate ventilation when working with this solvent, it is toxic.* Gently hold the acrylic strip to the board. Carefully and sparingly apply the solvent by slowly running the tip of the syringe along the adjoining edges. The solvent should easily flow between the two pieces as you move along the edge. If it does not, you may be applying too much pressure. You only need to hold the pieces together for about 10 seconds. During that time you may still move the strip if you need to make slight adjustments. Let the pieces set for 30 seconds before going on to the next step.

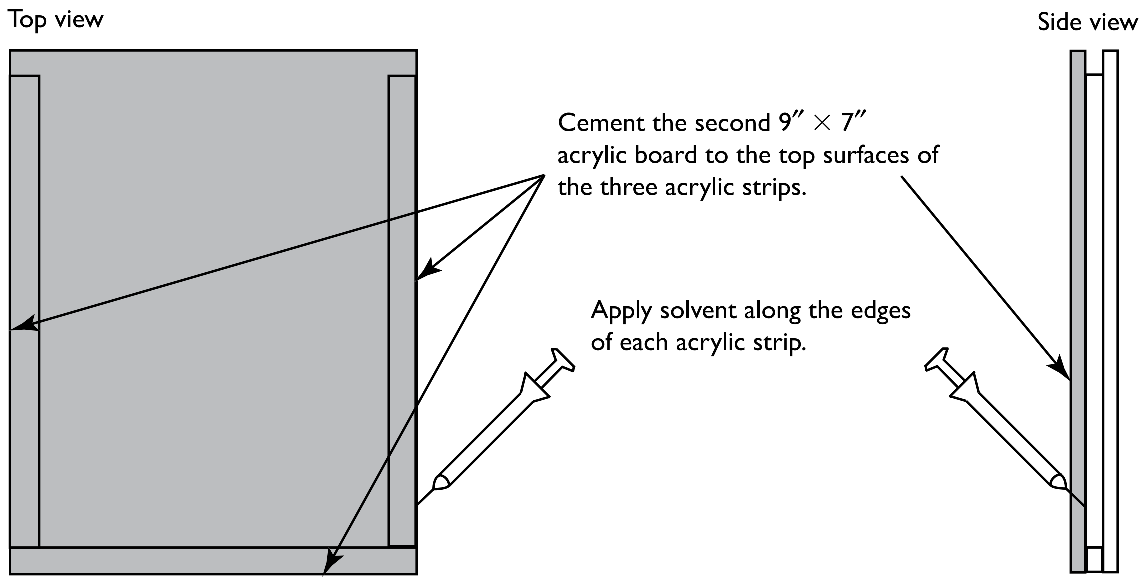
➤ **If using acetone as solvent, see the note on the previous page.**



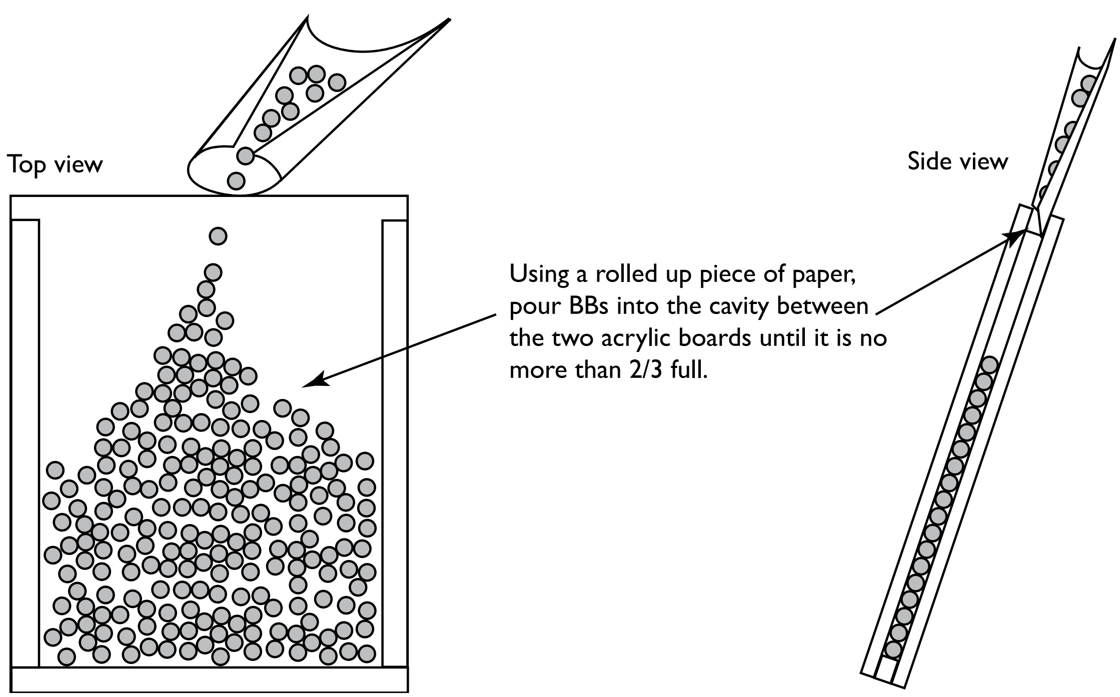
4. Position the two longer acrylic strips along the sides of the 9″ × 7″ board. Using the same technique as you did in step 3, cement these two strips to the 9″ × 7″ board and to the edges of the bottom acrylic strip.



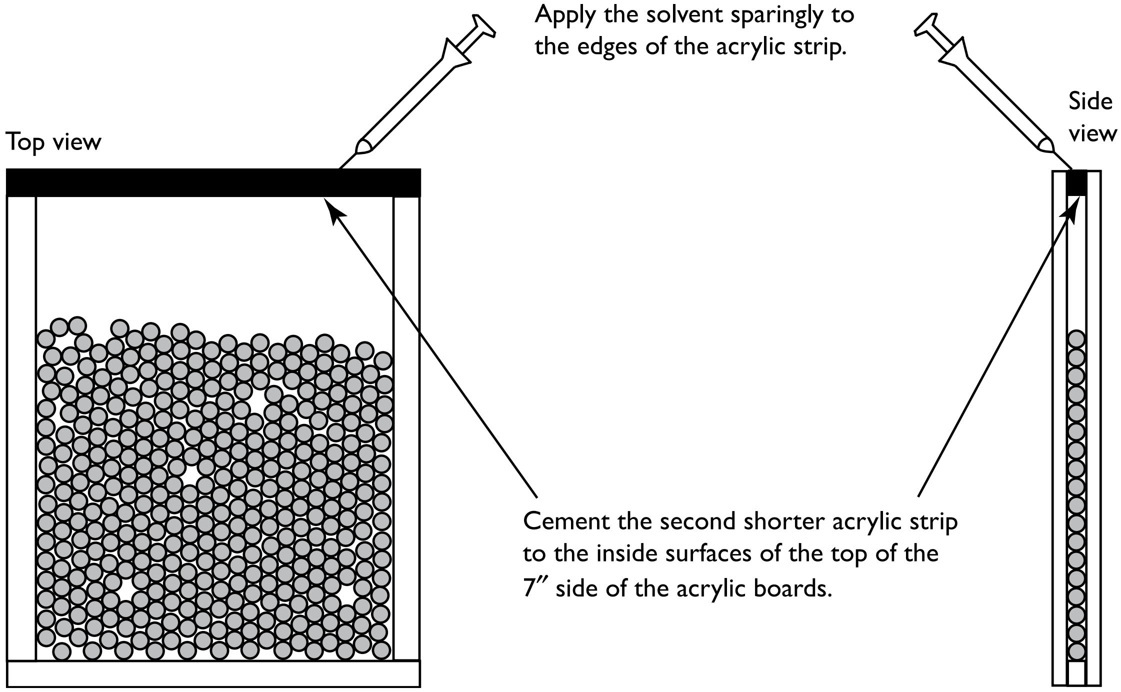
5. Remove any contact paper from the second 9″ × 7″ acrylic board. Place this board on top of the three acrylic strips so that the edges of the board are lined up with the outside edges of the three strips. Apply the solvent along the interface between this acrylic board and the three acrylic strips. **Allow the solvent to evaporate thoroughly before continuing, about 10 minutes.** (Tip the BB Board so that the solvent vapor, which is heavier than air, flows out of the crevices faster.)



6. Make a chute for BBs using a piece of paper. Pour the BBs into the cavity between the two 9″ × 7″ acrylic boards until the cavity is slightly less than 2/3 full.



7. To seal the BBs inside the cavity, place the second short acrylic strip between the two acrylic boards. Using a minimum amount of solvent, cement the 3/8″ surfaces to the inside surface of each acrylic board.



A BB Board Demonstration: Nanoscale Properties of Metals

The following material illustrates using a BB Board to demonstrate the nanoscale properties of metals.

Presentation: The Heat Treatment of a Bobby Pin

Materials

__ *2 steel bobby pins*

__ *Bunsen burner*

__ *tongs*

__ *1⁄2 cup water*

__ *BB Board*

I. Annealing

Procedure:

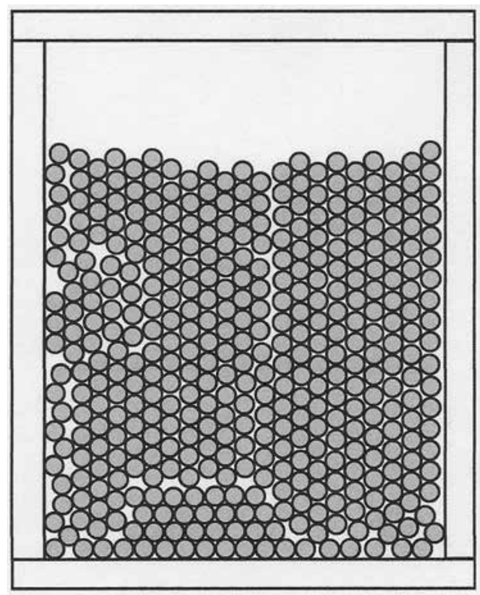
1. Heat the bent end of a steel bobby pin to a red-hot temperature in a Bunsen burner flame.
2. Remove the bobby pin from the flame and allow it to cool slowly.
3. Spread the ends of the cooled bobby pin. They will stay apart. The bobby pin is no longer springy.

Explanation: Heating to a red-hot temperature causes the metal atoms in the bobby pin to move faster and more freely. Slow cooling allows the atoms to adopt a more ordered arrangement causing a more perfect crystal of iron to form. The more perfect the crystal of a metal is, the easier it is to bend the metal because the atoms can "slide" past one another more easily.

This process of thermal treatment of a metal is called **annealing**. An example of annealed iron is wrought iron, which is easily bent into decorative railings.

BB Board Representation: Place the BB Board on the stage of an overhead projector and project the image of the BBs onto a screen. Explain that the BBs represent atoms of the iron. To represent heating of the bobby pin, slide the board rapidly from side to side. The BBs should shuffle into a random arrangement. To represent the slow cooling of the annealing process, decrease the rate at which you slide the board, moving the board back and forth ever more gently, watching the order develop. It may help to raise one end of the BB Board slightly.

It is common to see "holes" and a few "defect lines", as in the figure at right. The defect lines are seen because order develops with different orientations in different sections of the board.



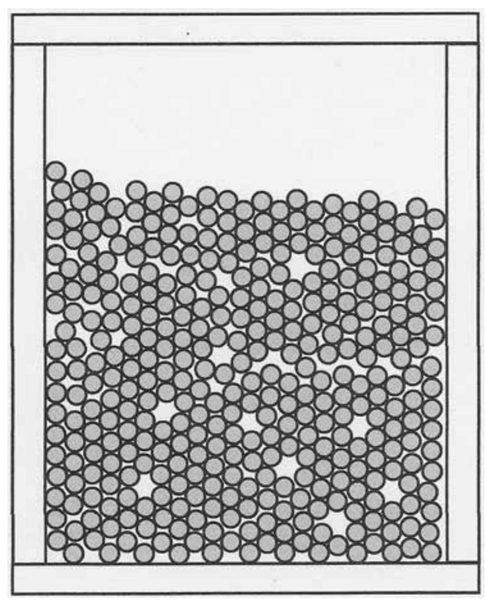
II. Hardening

Procedure:

1. Heat the bent end of a steel bobby pin to a red-hot temperature.
2. While it is red-hot, quickly immerse it into water.
3. Spread the ends of the cooled bobby pin. It breaks.

Explanation: Quick cooling of the red-hot, fast-moving, iron atoms freezes them into a disordered phase with many defects. The many small areas of order, separated by defect lines, do not allow the atoms to move past each other easily. In fact, breakage can easily occur along these defect lines. A **hardened** metal is hard, but brittle.

Knives keep a sharp edge because they are made from steel which has been hardened. They often break, however, when used for prying.



BB Board showing the disorder of atoms in hardened metal.

BB Board Representation: To represent the fast cooling of the hardening process, rapidly slide the BB Board back and forth to produce a random distribution, as in part I above. Then stop suddenly.

You should see many "holes" and "defect lines". When a hardened piece of metal is bent far enough, it will break along these defect lines.

II. Tempering

Procedure:

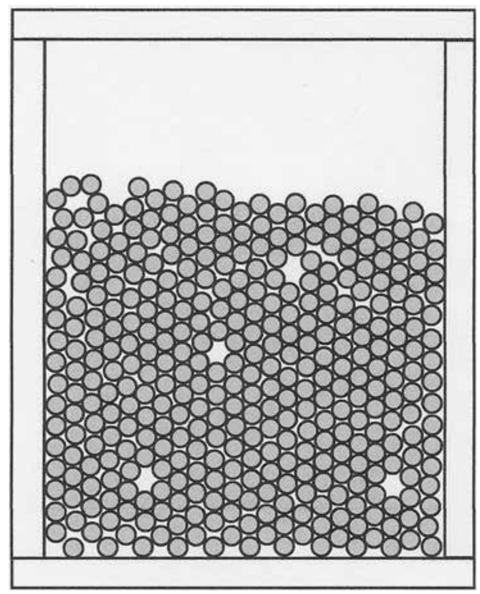
1. ⚠ Slowly lower the bent end of a **hardened** steel bobby pin into an area about 10 cm above the flame of a Bunsen burner. Heat it until an iridescent blue oxide coating is observed.
2. Remove the bobby pin from the flame and allow it to cool slowly.
3. Spread the cooled bobby pin and release. The metal should spring back.

Explanation: The process of gentle heating from the hardened phase is called **tempering**. This process introduces more order into the crystalline structure, somewhere between the annealed and hardened phases. The metal becomes springy.

Bobby pins and springs are made from iron that has been tempered.

BB Board Representation: To represent the gentle heating of the tempering process, start from the random distribution of the hardening process. Gently slide the BB Board back and forth until you see a few areas of order develop. Then stop.

You should see several areas of order separated by "defect lines". The degree of ordering of the iron atoms in the tempered phase is intermediate between the hardened and annealed phase.



BB Board showing the ordering of atoms in tempered metal.