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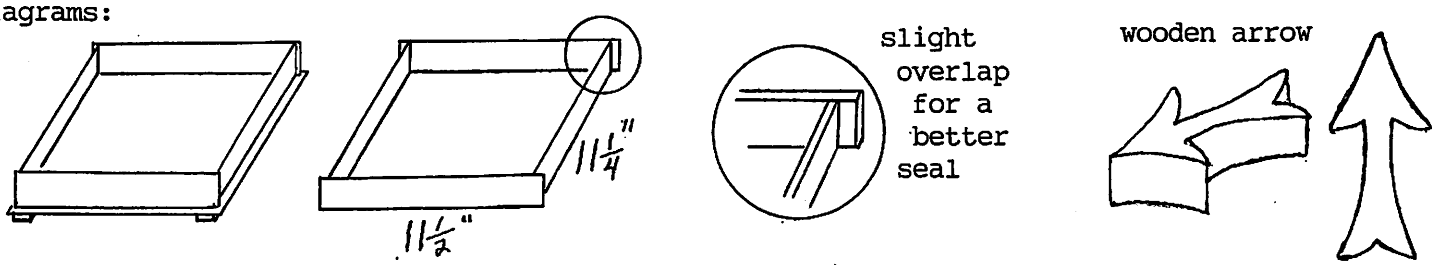
Magnetism and the acrylic tray - In the 1980's demonstrations on the overhead projector (OHP) were very popular because no other method was superior for large audiences. For example, an introduction to magnetism was especially dramatic on the OHP when using little compass needles and iron filings. But the OHP had an electric fan motor that attracted the filings. The solution was a transparent tray made from acrylic that would corral the filings and save them for reuse.

Beware! Acrylic has one great disadvantage compared to glass; it scratches very easily. Thus, it must be handled with great care. By adding little "feet", the tray's bottom can stay relatively scratch-free.

Today, if it is not commercially available, without too much effort, you can make one. The expertise involved is the same as that required to make the acrylic box in the "blue beer" demo.

Construction: Everything is made from 1/8" acrylic sheeting. The simple design calls for two, 2" x 11" side pieces; two, 2" x 11¼" side pieces; and one, 11½" sq. base piece. And some acrylic cement. The cutting requires a fine-toothed saw blade, usually 80 teeth or more on a 10" circular blade. Maybe a good plastics shop could cut out the pieces for you and even assemble it for "educational purposes".
Its construction is simple: lay out the sides on the base with overlaping corners. (See diagram.) With small pieces of masking tape, tape the corners so the sides match up and don't fall over. With all sides centered on the base, apply the cement along the outside seam with the base. When it has set, apply cement along the inside seam to seal the base. Next, remove the masking tape and seal a corner outside and inside; finish the other corners. If possible, cement ¼" thick acrylic "feet", ½" sq., to each corner on the bottom of the tray. Add clean water to the finished tray to check for leaks. Dump the water, dry the acrylic with kleenex, and add more cement to any leaking spots. Test again. Each time the acrylic must be softly wiped (not scrubbed) completely dry with kleenex to avoid water spots that will ruin the tray's transparency over time.
An added consideration. Because the magnetized compass needle can't be mixed in with the filings at the same time, something else is needed to indicate the field direction of the filings. A solution is small wooden arrows (see diagrams) cut out on a jig (scroll) saw that can be placed and left after the compass is removed; then sprinkle on the filings. The arrows are cut from 3/8" thick pine so they can be easily handled with fingers.

Diagrams:

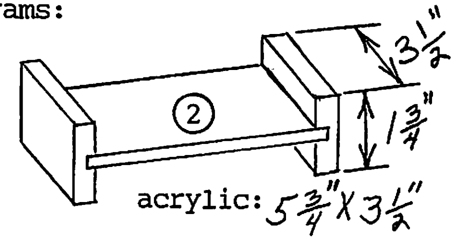


Presentation:
Part I - Remember, a magnetic field and its direction are equally important. An introduction to magnetism often begins with a lodestone on the OHP with a special compass needle for OHP's; test its field. Move on to the magnetic field around a simple, flat bar magnet (¼" x 3/4" x 6"); test its field. When ready to "show" its field with iron filings, carefully place the tray on top of the magnet. If the tray's bottom touches the magnet, add some masking tap to the feet until the tray just clears the magnet. Carefully sprinkle the filings in the tray all around the magnet and rap the side of the tray several times to help the filings form up the field lines. It should be an amazing sight! What you are looking at is what Michael Faraday observed in 1821 when he sprinkled filings on a damp piece of paper on top of a magnet and left it overnight to dry. The next morning he found that the filings had left little rust marks on the paper. He had a "picture" of a magnetic field! To "erase" the "filings field", just lift and tilt the tray to one side so the filings accummulate along one of the side pieces.

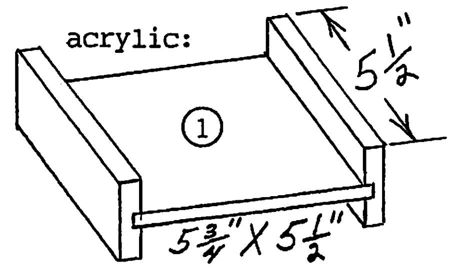
The next step, of course, is to take a second bar magnet and set up a N - S attraction field and study the field first with the compass and then with the filings.
Repeat the procedure for a N - N repulsion and then a S - S repulsion field, especially observing field direction.
If a U and/or horseshoe magnet is available, study its field with compass and filings, also.
When the permanent magnet study is completed, gather the filings in one corner of the tray and and pour them back into the shaker for the next demos. Some "iron dust" will remain on the tray. Carefully, lightly wipe it to one side with kleenex.

Part II - Once permanent magnets and their fields revealed themselves, electricity came along and added an entirely new, dominant dimension to magnetism. Names like Oersted and Ampere, along with Faraday and Henry, would elevate electromagnetism to overwhelming prominence in the nineteenth century. A set of three small pieces of apparatus ("frames") are required to show what these early, great scientists worked with and what they learned.
These "frames" are simply constructed from 3/4" plywood and 1/8" acrylic sheet; two are identical, the third only slightly larger. #16 soft, bare, copper wire will be added later.

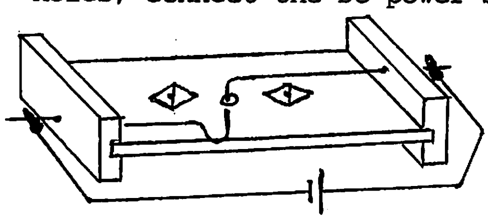
Diagrams:

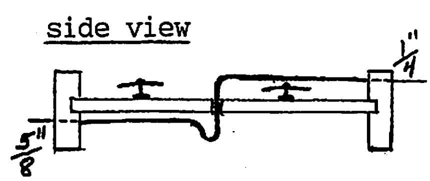


Saw the 3/4" plywood ends with a 1/8" x 1/4" deep groove down the center for the 1/8" acrylic. Press-fit (with Elmer's glue added?). Make ②. Make ①.



(a) For the Oersted effect, drill a single 1/16" (5/64") hole in the center of the acrylic on a drill press (if possible) for the #16 wire. Also, drill holes through the plywood to receive the wire (see diagram). Bend and straighten the wire while pushing it through the holes; connect the DC power supply with alligator clips.





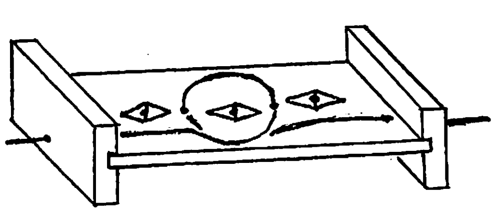
The compass must fit under the wire on the right side, but must not touch it.

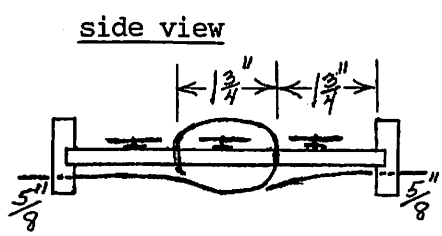
With the frame in the tray and the power on, test with the compass at each location, above and below the horizontal wire. Then beside the vertical wire. Some deflection should occur at each location indicating the presence of a magnetic field as Oersted observed in 1820. Remove the compass, and shake some filings around the vertical wire. Are there any slight concentric circles of filings around the wire, especially near it? Again, gently rap the frame of the apparatus to help the filings align better.

Note: The "frames" in the tray are in a "delicate" situation, that is, try not to get filings under the plywood frames that will cause bad scratching of the tray. Some scratches will occur despite your best efforts, but try to minimize the "damage". Always lift the frames straight up (and down) and tip them toward one side of the tray to remove the filings. Gently wipe the center area of the tray "clean" before lowering the next frame into the tray.

(b) The second frame contains one loop, the beginning of an electromagnet. Its construction is similar to the first frame; only the placement of the wire holes is different (see diagram). 5/64" holes may be easier to work with this time.

Diagrams:



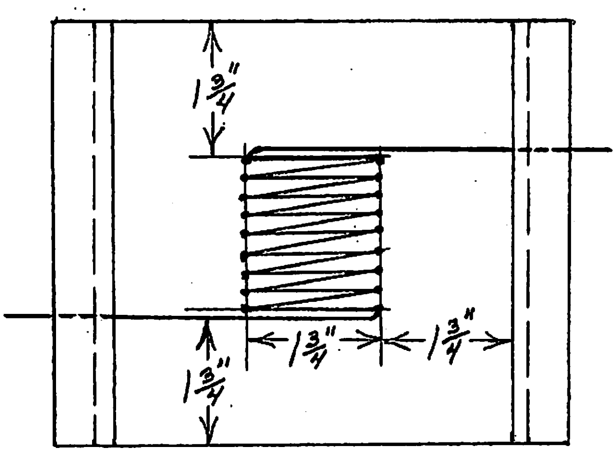


The compass must fit inside the loop. The bare wire in the loop(s) must not touch each other.

The "diameter" of the loop (1 3/4" in the diagram) depends on the length (size?) of the compass needle; you must decide and space the wire holes in the acrylic accordingly. The loop can be oval-shaped (slightly "flattened") for convenience. When ready to show, move the compass inside and outside to show the field and its direction. Remove the compass and demonstrate with the filings; remember to rap the frame. Do you get a faint "picture" of the field?

(c) The third frame, the helix with more loops, is the culmination of all you have learned so far and what an electromagnet is all about, the superior replacement of a permanent bar magnet because you can do so many remarkable things <u>inside</u> the "magnet" using its uniform, stronger field. Of course, you can also turn it on and off, and easily change its strength arbitrarily which you can't do with a permanent magnet.

Diagram: <u>top view</u>



Its construction is the same as (b), the second frame, except for more wire holes for more loops (9). Keep the loop size the same. Drill 5/64" wire holes ¼" apart. Of course, two rows of nine holes each are required. If the acrylic is bare (no paper cover), apply strips of masking tape in the areas where each row of holes is to be drilled. Mark the hole positions, drill the holes, and remove the tape. Working the wire through the small holes will be trying. From (b) you can figure out about how much wire you will need; cut it extra long. Start with the center loop and work toward each end using your fingers to pull and shape the loops as you go along. They don't need to be perfect. If you choose to use pliers, wrap the jaws in masking tape so as not to mar the wire; roughed up wire is difficult to work through the small holes. The side view of the helix is the same as (b).

When ready to show, follow the same procedure as in (b) with the compass and filings. With nine times as many loops, you will notice much clearer filings patterns created by the much stronger field, expecially <u>inside</u> the helix. Note the parallel lines making up the uniform field. Are the results worth the effort to make this frame? You bet! When finished, return the filings in the tray to the shaker and carefully wipe clean the frames and tray with kleenex. Dust-free storage is recommended. Always remember, keep scratches to a minimum, and these acrylic pieces will serve you well.

Addendum: Hallelujah! Another interesting use of the acrylic tray is the determination of the index of refraction, n, of water! This time it is measured by using the speed of a wave equation, v or c = λ f, and Young's equation, λ = xd/l, not Snell's law.

$$n = \frac{c_{air}}{v_{water}} = \frac{\lambda \cancel{f}}{\lambda \cancel{f}} = \frac{x \cancel{d/l}}{x \cancel{d/l}} \Rightarrow n = \frac{x_{air}}{x_{water}}$$

Materials: tray, laser, diffraction grating, copy paper, shears, tape, pencil, water, ruler (metric)

Preparation: (a) on one side (outside) of the tray, tape a diffraction grating of known d; on the opposite side of the tray, tape a white paper "screen" (outside).

(b) Add water to the tray up to (even with) the middle of the grating.

(c) Position the laser beam so it is just below the waterline. Mark L_o and L_1(s), thus x for "water" on the screen.

(d) Tilt the laser up until the beam misses the water but hits the screen. Mark L_o and L_1(s), thus x for "air" on the screen.

(e) After use, remove water and tape immediately. Wipe dry; do not rub. Is n = 1.33 ?