

# The Workshop

*The first item we will have in our workshop is a tornado simulator. It is only one of a number we know how to build, and it also one of the easiest and least expensive. We hope you enjoy building and experimenting with it.*

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## Tornado Simulator

The new Tornado Project video, [Secrets of the Tornado](#) will, among other things, show a number of different "model" tornadoes that can be made very easily and inexpensively at home. Most are made with items you already have around the house, or are readily available at a hardware or discount store. Some components were found at yard sales, flea markets, or are the kinds of materials stores throw away. And they are easy to build! In that spirit, we are providing the following tornado simulator plan for The Workshop.



This simulator is great for science fairs, science projects or reports, or just for fun. And if you are like us, you will find them both fun to make **and** mesmerizing to watch.

Although we are providing the model plans, we do not intend to supply the extensive directions the video guide will have. We will also not go into the "science" of models as the video will. But this will get anyone who wants to make a model a good start. Does it work? Check out this Lyndon State College meteorology student with it!

### Materials

#### cardboard

If you can find a 24" high box that is 12" on each side you can cut the bottom and top off and save time. Since that is an odd size, however, we are assuming that you will have to assemble enough cardboard to create one that size.

#### plastic

This can be plastic wrap, Saran wrap, clear plastic on a roll, or a sheet of clear, hard plastic. The hard kind will make a better window, but is more expensive if you have to buy it.

#### flat black paint

This is for the inside of the box. Latex paint dries very quickly and cleans up easily, so that is what we use. If you don't have paint or don't want to paint, you can use some other black background material that can be secured to the inside of the box. However, the duller the finish, the less likely it is to reflect light back and the easier the vortex will be to see.

### **duct tape**

Duct tape will be used to connect the pieces of cardboard so that they create a box.

### **hot plate**

The higher the wattage, the quicker it will heat the water.

### **pan**

You can experiment to see which kind of pan gives you the best results. We use a cake pan.

### **water**

The steam from the boiling water will be the "tracer" that will allow you to see the vortex that forms. The more "tracer" you have, the easier it will be to see the vortex.

### **light source**

This light will be directed into the simulator chamber to light up the vortex, so a "directional" light is better than a lamp that shines light in all directions. A "shop light" standing upright works well if you can find a way to keep it upright and steady. In a pinch, you could use a lamp and direct the light with aluminum foil.

## **Tools**

**Working with cutting tools and hot plates can be dangerous. Students and children should have adult supervision if they undertake this project.**

***Legal stuff: The Tornado Project is providing the instructions for this simulator, but cannot be held responsible for any cuts, burns or other injuries incurred during the creation or operation of this model.***

### **meter stick or yard stick**

If the meter stick is metal, you can use both to measure the cardboard and as a straight edge when you are cutting it.

### **tool to cut cardboard**

This can be scissors, a utility knife, or a kitchen knife--whatever works best on the kind of cardboard being used.

### **tool to cut plastic**

If you purchase clear, hard plastic from a "glass service", they will cut it for you. If you use plastic wrap or roll plastic, scissors will do.

### **paint brush**

We use the disposable foam kind to paint the model. Then we wrap the brush tightly in plastic wrap or foil and freeze it until we know that we are done with it. After the model is fully put together and working, you may need to touch up spots.

### **firm but "unimportant" cutting surface**

Do not do your cutting directly on furniture or finished floors unless you are willing and able to purchase new furniture or floors for your wife/husband/girlfriend/boyfriend/mother/father! Do

your cutting on an old piece of plywood, several layers of hard cardboard, a cement floor, or other firm surface that can withstand the damage.

## Directions

**Use the meter or yard stick to measure and mark each item before you cut. Use extreme caution in cutting.**

### Step 1:

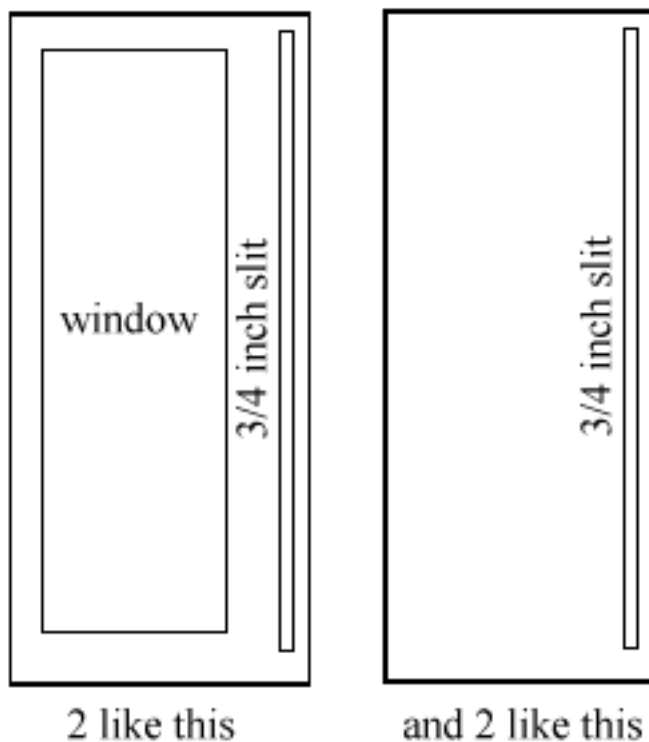
Cut the four sides of the simulator chamber. Each side should be 12" wide and 24" long. If the piece of cardboard is big enough, you can make all sides in one piece, then score the corners so that they can be bent to form a 90 degree angle.

### Step 2

Cut a 3/4" wide slit in each side. The slit should begin about 2" up from the bottom, and end about 2" down from the top. It should be positioned about 3/4-1" from the corner.

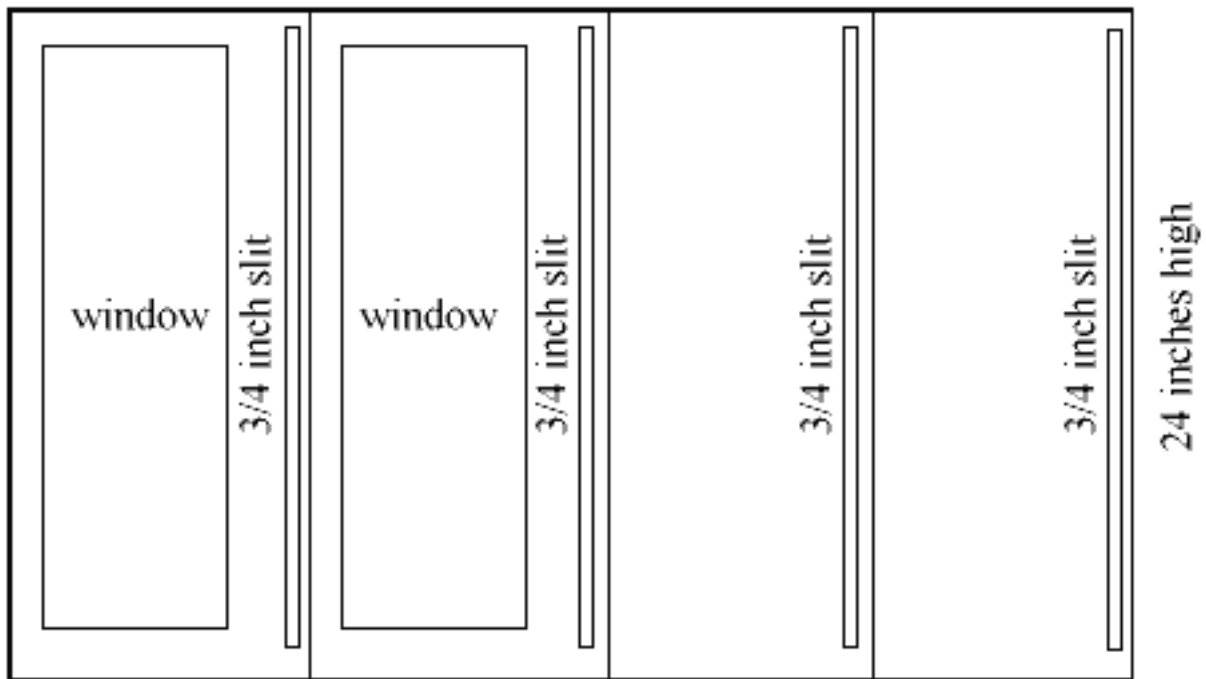
### Step 3

Cut "windows" in two sides. The windows can start 2" to 3" above the bottom and end the same distance from the top. The size of the windows is not critical, but allow enough of a cardboard "frame" so that it will still stay flat and strong. These sides will be adjacent to one another, **not** on opposite sides of the chamber.



### Step 4

Lay the four sides out like the diagram below and tape three corners together with duct tape.



12 inches on a side for a 48 inch circumference

**Important:** note the position of the slits on each side.

### Step 5

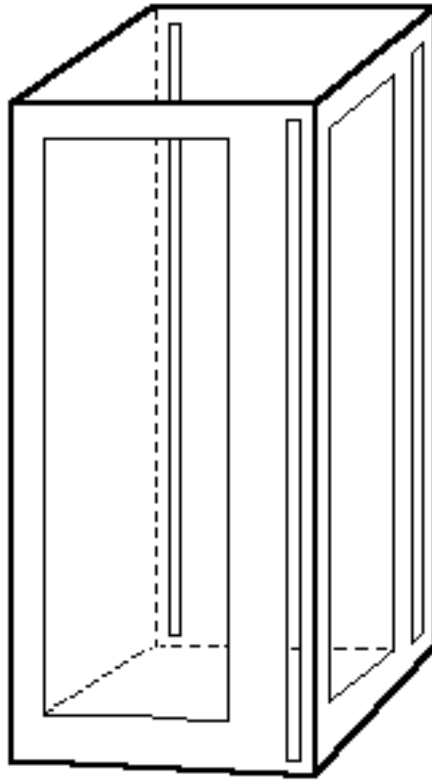
Paint the inside surfaces with black paint and let them dry thoroughly. [See note](#) about the paint brush.

### Step 6

Cover the "windows" with plastic. You can duct tape them to either the inside or the outside of the simulator.

### Step 7

Tape the fourth side of the model so it creates a box with no top, no bottom, 4 slits, and two windows.



## Running the Tornado Simulator

To run the simulator is simple. The hardest part is making the vortex **visible**.

**Step 1:**

Place hot plate on a firm surface, plug it in and turn it on high.

**Step 2:**

Place a pan of hot water onto the hot plate and bring it to a boil

**Step 3:**

Position the simulator chamber over the hot plate with one window facing towards you and one window facing towards the side. In the photo, Aimee is behind a model that is already set up.

**Important note:** if you want cyclonic rotation, position the chamber with the slits on the right side as they face you.

**Step 4:**

While the water is heating, position the light source so that it shines through the side window and lights up the interior of the simulator chamber.

**Step 5:**

When the water boils and forms water vapor, the vortex will be visible. The more vapor, the more visible the vortex will be. Do not let the pan boil dry. If you refresh the water in the pan with more hot or boiling water, you can keep the vortex going easier--cold water will cool it down too much.



## Troubleshooting

**What if the vortex is wobbly?**

The size of the pan can make a difference. In our experience, a large pan tends to make the vortex wander around. In the course of wandering, it steams up the plastic windows. Trying different size pans will let you refine the system.

**How can I make the vortex easier to see?**

It is actually harder to make a tornado model visible than it is to make the simulator in the first place. A bright light shining directly down into the box can make it easier to see. The light cannot be too close to the top of the box, however, or you will block the rising air. Many more tips and

hints will be given in the upcoming video, as well as several more models.

## Experimenting with the Model

### How can I experiment with the model?

You might first experiment with the width of the slits. Start by making them 1 1/2 inches wide, then use masking tape to make the slits 1 inch wide, then 1/2 inch wide, then 1/4 inch wide and see what this does to the shape and speed of the vortex.

Another experiment can be done by completely blocking up part of the slit vertically. For instance, try covering up the upper half of the opening, then try covering up the middle third of the opening, then try covering up the bottom third of the opening. All of these will somehow change the character of the vortex. I can't tell you exactly how, because you may not be using the same brand of hot plate or the same shape pan we are using. Each combination of "variables" affects the outcome. The shape will be different or the strength of the heating element will be different. You will always get better results with a higher wattage hot plate. The vortex will be pretty weak if the hot plate is under 1000 watts. You need at least that to get enough steam. Camp stoves can produce rapidly boiling water, but if you make your box wider to accommodate a camp stove, you will also need to make it taller. The proportions are important.

## Learning from the Tornado Simulator

### How does the simulator actually compare to a tornado?

The proportions in the model need to be correct in order to create a vortex. This is probably true of tornadic vortices also. Too little updraft, too much updraft, too little inflow (too narrow a slit), too much inflow at too low a speed (too wide a slit), and no vortex will form. You will get circulation, but no concentrated vortex at the center. This particular model is more of a model dust devil than a tornado. This is because the heat source is at the bottom. Real life tornadoes have their energy sources overhead, so you will need to introduce a small fan at the top to better model a tornado. If you use a fan, you begin to get beyond the scope of this design, and I prefer not to go any further into it. But I will make one suggestion. If you introduce a small, weak fan, make the box wider and taller.

### Just what physical processes are involved here?

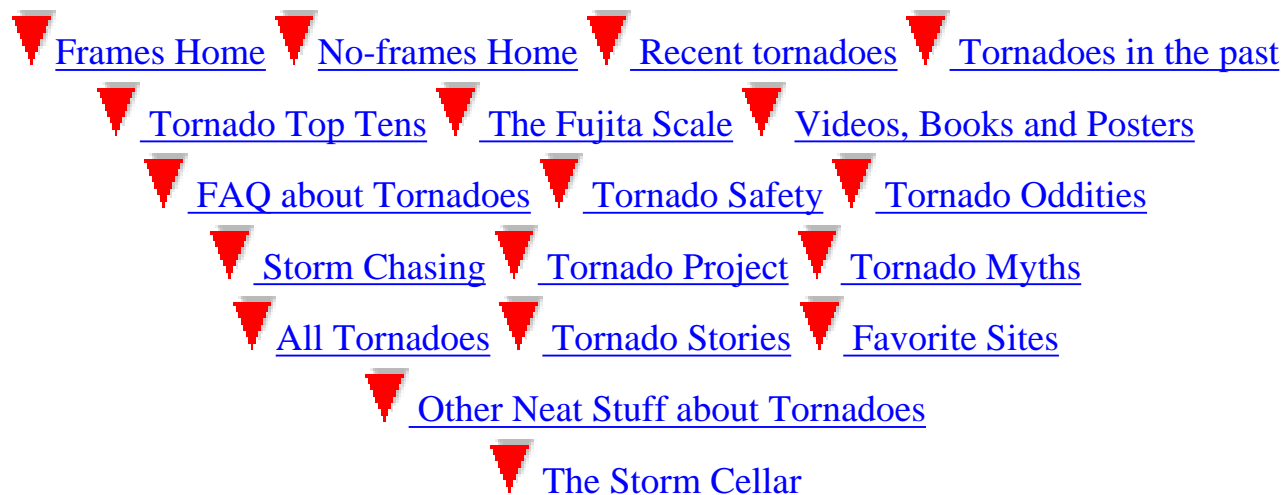
Air coming in the slits produces what is called "wind shear". The model may work with just two slits in opposite corners. This would be classic wind shear, with adjoining air flows moving in opposite directions and interacting with one another. This interaction will create a swirl, but not a vortex. The second necessary ingredient (in both tornadoes and models) is the updraft. So we have horizontal wind shear below, and an updraft.

### Exactly why does the vortex form?

After you have your Master's degree in meteorology or fluid mechanics, you can explain it to me! That is a very difficult question to answer and well beyond the scope of this page. If forced to give an answer, I would have to simply say that a vortex is necessary so that things like energy

and momentum are conserved. Energy and momentum both involve speed. Energy and momentum aren't destroyed or increased. In order that they both stay unchanged, a vortex needs to form. It's really all mathematics, and I am going to stop before I put down an equation.

**If you want to use frames, you will get more reliable results by using the navigation panel on the left.**



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